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THE SEMI-CENTENNIAL OF THE WORLD'S FIRST TESTS OF THE DYNAMO.

As is well known, the dynamo as an instrument for the production of electrical currents is about one hundred years old. It was known and used by various investigators but was never tested before 1877. In the winter of 1877–78 three different makes of dynamos were tested in the Hall of The Franklin Institute, Philadelphia—photometrically, mechanically and electrically, for the first time in the world's history. The machines tested were Gramme machines, Wallace-Farmer machines and Brush machines. As a result of these tests the Committee recommended the purchase by the Institute of a Brush machine, which had shown an efficiency of thirty-one per cent. That instrument is now in the possession of the Institute. The tests were carried out by a committee from the members of The Franklin Institute, made up as follows:

J. B. Knight, Secretary of the Institute, Chairman; Dr. Robert E. Rogers, President of the Institute; Prof. Pliny Earle Chase, Professor of Philosophy and Logic, Haverford College; Robert Briggs, Consulting engineer; Dr. Edwin J. Houston; Dr. Elihu Thomson; Theodore D. Rand, lawyer; Washington Jones, engineer; Samuel Sartain, artist and engraver.

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The electrical tests were made by Professors Elihu Thomson and E. J. Houston, the results of which were published in full in the Journal of The Franklin Institute.

On April 18, 1928, the Institute held a set of exercises in celebration of the semi-centennial of these original dynamo tests. A group of distinguished and representative scientists gathered in the afternoon of that day in a meeting which was addressed by Dr. Charles F. Brush, inventor of the original arc light system of illumination and of the arc light dynamo purchased by the Institute, and inventor of the first practical storage battery; and Professor Elihu Thomson, inventor of the Thomson-Houston arc light machine and the world's original 'dynamo tester.'

The meeting in the afternoon was followed in the evening by a dinner given in honor of the two speakers. The papers which were read at the semi-centennial exercises follow.

SOME REMINISCENCES OF EARLY ELECTRIC LIGHTING.

BY

CHARLES F. BRUSH, Ph.D., LL.D., Sc.D.,

Member of the Institute.

THE present period of human civilization is often called the "Age of Electricity." Almost everything nowadays is done by, or with the aid of, electricity. The applications of electricity have profoundly modified and enriched human life. And all of this change (except the telegraph) is embraced in a period of fifty years; a period well within the memory of the older generation now living. To better realize the extent of the revolution that has occurred in everyday life, try to imagine ourselves today without any electric light; without the telephone or radio; without the trolley car, or electric elevator for our high buildings; without the many domestic electrical conveniences; without industrial electro-metallurgy; without the vast distribution of cheap power we now enjoy, and without hydro-electric development of our waterfalls. A rather gloomy picture of life only fifty years ago.

I am often asked what first drew my attention to the electric arc-light—a mere laboratory curiosity not so very long ago—what inspired my belief in its industrial possibilities, and led me to work out the many necessary inventions which finally led to commercial success.

These questions are not readily answered. Keen but passive interest in the brilliant experiments of Sir Humphry Davy, and others of later date, followed by much thought, study, and experiment, led gradually to the fixed idea. It was an evolution covering a period of years.

From early boyhood I was an omnivorous reader of scientific literature. Such parts of astronomy, chemistry, and physics as I could understand were a never-ending source of delight. I also constructed much crude apparatus —telescopes, microscopes, and photographic appliances.

In my early high-school days I made, among other things, many pieces of electrical apparatus—static machines, Leyden

jars, batteries, electromagnets, induction coils and small motors. But the electric arc as described in the text-books, with its dazzling light and intense heat, was for a long time beyond my reach. Not until 1865 was I able to produce a real arc-light, a very small one indeed; but it was the first I had ever seen, and it filled me with joy unspeakable. I had to make the necessary Grove batteries for the purpose, using lumps of gas retort carbon instead of the customary strips of platinum which I could not afford to buy. In the early seventies I constructed a first-rate induction coil of unique design, giving very fat four-inch sparks. It had only six miles of *bare* secondary wire so wound that contiguous turns could not contact.

Soon after my first little arc-light, came the news of Wilde's experiments in London with his crude dynamo and single arc-light. The light was probably about the size of our ordinary street lights; but it was deemed a wonder at that time, and interested me so much that I wrote a graduation essay on it the following year (1867).

In the early seventies the Gramme dynamo made its appearance in Paris. It was the first really efficient dynamo, and excited wide-spread interest. Some stores and factories were lighted by it at that time, but a separate dynamo and complicated clockwork lamp were required for each light, and these were too expensive for general use.

Some queer notions about the electric light were prevalent. As late as 1873, Deschanel's "Natural Philosophy," a well-known text-book, said: "The light of the voltaic arc has a dazzling brilliancy, and attempts were long ago made to utilize it. The failures of these attempts were due not so much to its greater costliness in comparison with ordinary sources of illumination, as to the difficulty of using it effectively. Its brilliancy is painfully, and even dangerously intense, being liable to injure the eyes and produce headaches. Its small size detracts from its illuminating power—it dazzles rather than illuminates—and it cannot be produced on a sufficiently small scale for ordinary purposes of convenience. There is no mean between the absence of light and a light of over-powering intensity."

The advent of the Gramme machine interested me deeply,

and from that time the industrial possibilities of dynamos were never out of mind.

Early in 1876 I completed drawings for a dynamo of my own designing. This turned out to be a distinctly new type, since known as the "open-coil" type, preëminently well fitted for production of the high-tension currents necessary for series arc-lighting, which developed later.

Such parts of that first dynamo as required machine-shop work were made under my direction at the shop of the Telegraph Supply Company, and together with necessary materials were shipped to my old country home near Wickliffe, Ohio, where I spent my summer vacation in 1876. There, in the little workshop where I had made my first crude electrical apparatus in boyhood days, I wound the armature and field-magnets, and completed the machine.

The day of trial was a memorable one for me. I belted the little dynamo to an old "horse-power" used for sawing wood, and attached a team of horses. After a little coaxing with a single cell of battery to give an initial excitation to the field-magnets, the machine suddenly "took hold," on short circuit, and nearly stalled the horses. It was an exciting moment, followed by many others of eager experiment. That was my first acquaintance with a dynamo.

This pioneer machine was long preserved, and formed a part of the United States Government Historical Exhibit at a subsequent Paris Exposition.

The little dynamo was next taken to the shop of the Telegraph Supply Company, where steam power was available, and testing work was continued, while plans for further development were beginning to take shape. A small clockwork arc-lamp was constructed and used with the dynamo.

My personal friend, Mr. George W. Stockley, was president of the Telegraph Supply Company, and he agreed with me that there were very promising commercial possibilities in development of electric light. Thereupon business arrangements were made by which the Company undertook commercial exploitation of the new dynamo and such other electrical inventions as I might make.

In the autumn of 1876 the Telegraph Supply Company began the manufacture of dynamos of the new type adapted

to electroplating. A considerable business was developed in this direction. It is of historical interest that my compound field winding for constant potential, so generally used in incandescence lighting and power transmission, was first applied to plating machines. It was, in fact, invented for that purpose in the autumn of 1877.

During the autumn and winter of 1877 and 1878 two of the new dynamos built for lighting were exhibited and tested at the Franklin Institute in Philadelphia. In connection with the dynamos, a new lamp of very simple construction was also exhibited. This, since known as the "ring-clutch" lamp, was the first simple lamp which appeared, and it marked a very great advance in the art. Costing perhaps a quarter as much to make as other lamps then used, it was far less liable to derangement. Its salient features have been embodied in nearly all arc-lamps ever since.

During the testing of the two Brush dynamos and others, and the Brush arc-lamp in the fall and winter of 1877–78, I visited the Franklin Institute several times and made the acquaintance of Professor Elihu Thomson who conducted the tests. This was the beginning of a warm personal friendship which has continued unabated through fifty years.

The first dynamo and lamp actually sold by the Telegraph Supply Company were shipped to Dr. Longworth of Cincinnati about January, 1878. I went down to Cincinnati to show the Doctor how to run his machine, and one evening while I was there he exhibited the light from the balcony of the building in which he lived, on one of the principal streets. It was a four-thousand-candle light, and of course, attracted a large crowd, every man of which was ready and willing and eager to tell his neighbors all about it. I mingled in the throng for a time to hear the comments. One man who had collected a considerable audience called attention to the solenoid at the top of the lamp and said, "That is the can that holds the oil"; and, referring to the side rod, said, "That is the tube which conducts the oil from the can to the burner." He said nothing at all about electricity—a little oversight apparently unnoticed by his hearers; they went away happy in their newly acquired knowledge of the electric light.

The early single-light machines were quickly followed by two- and four-lighters: that is to say, machines furnishing two or four separate and distinct currents, each adapted to operate a single arc-lamp.

Then began the tedious education of the public to the new light. The principal difficulty arose from the propensity of everybody to stare directly at the arc, and then declare that everything else looked dark. It took years fully to outgrow this habit. I had often to ask, "Why don't you stare at the sun if you wish to be dazzled? It is vastly brighter than the electric light." Furthermore, most early purchasers of electric lights thought each lamp giving as much light as fifty gas-burners would replace fifty gas-lights, notwithstanding the great advantage of distribution possessed by the latter. Altogether too much was expected.

However, a number of two- and four-light units were sold during the season of 1878 for lighting stores and shops. The largest plant of this kind, about twenty lights, was bought by Mr. John Wanamaker for his great department store in Philadelphia.

A four-light dynamo and lamps were used to light a part of the Mechanics' Fair in Boston in the autumn of that year. The electric light was a novelty in Boston at that time, and a great attraction at the fair.

One of the earliest four-light machines was exhibited to a number of invited guests at the works of a large manufacturing company in Cleveland. One gentleman on that occasion looked the whole apparatus over very carefully for perhaps half an hour, and then, pointing to the line wire, said to me, "How large is the hole in that little tube that the electricity flows through?" The shop superintendent of the company observed the machine for perhaps five minutes in complete silence; then he had fully digested the whole matter, and was ready to explain it to me. He said: "The electricity is generated by that there revolving affair rubbing the air up against them iron blades (meaning the pole-shoes of the magnets), just as you get sparks when you rub a cat's back." I suggested that while his was a simple and beautiful theory, it did not fully meet the facts. But he would hear nothing from me. He said: "The whole thing is plain. If you

should run that machine in a vacuum, where there is no air to get rubbed, you couldn't get any electricity."

The year 1878 was a memorable one in the history of electric lighting. Not only did it witness the first industrial use of electric lights on any considerable scale, but it was in that year that I had the great good fortune to invent and develop the modern series arc-lamp with its regulating shunt coil. It was this invention that made arc-lighting from central stations commercially possible; and I think it may justly be regarded as marking the birth of the electric-lighting industry.

It had become evident by this time that a "fool-proof," or nearly fool-proof, lamp was essential to commercial success. The users of lamps could not be induced to let them alone, and no end of trouble was caused by meddling with them. So, in designing the new series lamp, I endeavored to make it completely fool-proof, and nearly succeeded, but not quite. The mechanism was locked together like a Chinese puzzle, and difficult to get apart. It was entirely devoid of screws that could be taken out and lost, or adjusting devices with which users could tinker. All necessary adjustments were made in the shop when the lamp was tested, and were made permanently. But of course it was possible to take a lamp apart, and in this sense it was not fool-proof. Complaining of a lamp which failed to operate, a man once said to me, "Why I've had that lamp all to pieces four times, and yet it won't work."

The high-tension dynamos for series lighting were "fool-killers," and usually able to look out for themselves. They discouraged undue familiarity.

Of course "series" lighting immediately superseded "parallel" lighting. A single large dynamo and one lamp circuit were much cheaper, simpler, and more easily managed than several small dynamos and many lamp circuits. Furthermore, the line cost and losses were vastly less, thus permitting the location of lamps at any desired distance from the dynamo —miles, if necessary. The stimulation of the business by the introduction of series lighting was enormous.

The first series plant, a six-light outfit, was sold in December, 1878, for lighting a clothing-store in Boston. One of the lights was hung over the sidewalk in front of the store,

and nightly attracted crowds of people. This was the first electric light ever used in the streets of Boston.

Quickly following the six-light machines came the sixteen-lighters; and they remained the standard size until late in 1880, when they were followed by the forty-light machines.

One of the earliest sixteen-light outfits was installed, in February, 1879, in a worsted-mill at Providence, Rhode Island; another was purchased in March, another in April, and two more in September, making eighty lights in all—the largest electric light plant in the world at that time. Other purchasers of plants in 1879 were mills in Providence, Hartford, and Lowell, a hotel in San Francisco, and several New York dry-goods houses.

Many plants were sold in 1880, and by the end of that year about six thousand lights had been installed.

Of course it was difficult to educate men fast enough properly to install and operate the plants, and much annoyance was caused by trivial accidents and poorly constructed and poorly insulated lines, which led to "short circuits" and "grounds." It often fell to my lot to straighten out these troubles. Once I traveled fifteen hundred miles to take a common staple tack from the bottom of a dynamo, where it happened to short-circuit a field-magnet. Sometimes malicious tampering with the dynamos occurred, but, fortunately, not often. Long, fine wire nails were occasionally found driven into the field-magnet coils in inconspicuous places.

Some difficulties were never traced to their source. On one occasion sixteen lamps were returned by our Boston agent with the statement that his men were quite unable to make them work decently. I examined and tested the lamps carefully, and found them all right. Without making any change or adjustment whatever, except to change the numbers so as to conceal their identity, I sent the lamps back, with a letter stating that I had personally examined and tested this lot, and could guarantee them to be all right. They were put back in their original places, and worked beautifully, so the agent said; and he requested me as a personal favor to look over all lamps he might order in the future before they were shipped. He wanted to know what was the matter with the first set, but I never told him.

We had much trouble with carbons in the early days. Our first carbons were crooked and soft. They had high electrical resistance, burned out rapidly, and were very expensive. They were made from gas-retort carbon, which was difficult to pulverize, and contained from three to five per cent. ash. The ash was fatal to the steadiness of the light, causing the arc to flicker badly. It was necessary to find some better material than gas-retort carbon without delay.

After much anxious thought and prolonged study of industrial processes likely to yield such material, I hit upon "still coke," a by-product of the destructive distillation of mineral oils. As the result of many analyses of different specimens of this substance, it was found that by careful selection the ash could be kept as low as two or three hundredths of one per cent. Still-coke could be pulverized with comparative ease, and was obtainable in unlimited quantities at small cost. It has ever since been almost everywhere used in making carbons.

But the early carbons made from still-coke shrank enormously in baking, and consequently were very crooked. Much experimenting was necessary to find out how best to work with this material. Then, too, special machinery and furnaces had to be designed for grinding, mixing, molding and baking. These details occupied much of my time during the first two or three years.

To decrease their electrical resistance and retard the burning of the carbons, we electroplated them with copper. This little scheme of covering the carbons with just enough, but not too much, copper was the only easy invention that it was my privilege to make; and it paid well, considering its seeming simplicity. It yielded, if I remember correctly, something like $150,000 in cash royalties before serious competition set in.

The very early carbons were sold at the rate of $240 a thousand. I say at the *rate* of $240 a thousand, because nobody thought of ordering a thousand carbons at once. Fifty or a hundred were ordered at a time. When the business increased a little, we reduced the price to $150 a thousand. This involved loss for a time, then covered cost,

and afterward afforded profit as the business grew larger. We soon again reduced the price, this time to $62.50, on the theory that cheaper carbons would stimulate the growth of the electric-light industry; and our expectations were abundantly justified. The growth of the lighting business was very rapid from that time on, so that while we lost money on carbons at first, we far more than made it up in increased sales of dynamos and lamps. After a while, however with largely increased and growing output, we made a handsome profit.

During the first ten years or so of the electric-lighting business, the price of carbons gradually settled down to about ten dollars a thousand, and remained not very far from that figure. But the quantity used grew to amazing proportions. Before the introduction of the "inclosed-arc" lamp, the annual consumption of carbons reached nearly two hundred millions.

The first instance of permanent public-street lighting anywhere in the world was in the Public Square of Cleveland, a little park of about ten acres. In April, 1879, twelve lamps of the ordinary so-called two-thousand-candle power were installed in the park on high ornamental poles.

While we were putting up the poles and line circuit, a great deal of interest was manifested by the public, and on the evening when the lights were formally started the park was crowded with people. Many evidently expected a blinding glare of light, as they had provided themselves with colored spectacles or smoked glass. Of course there was at first a general feeling of disappointment in this respect, although everyone was willing to admit that he could read with ease in any part of the square. After a few weeks, however, when the novelty had worn off, and the people had tired of staring at the lamps, the general verdict was highly favorable to the new light.

As the Public Square lights were required to burn all night, this necessitated putting fresh carbons in each lamp sometime during the night, because a single set would not last until morning. But the nightly trimming of the lamps required an extra man and added materially to the cost of lighting. To meet this difficulty, I devised the "double-

carbon" lamp, which afterward grew into general use for all-night lighting, and became famous through much patent litigation.

The new lights were exhibited in London in 1880. For that purpose we sent over a sixteen-light outfit and some smaller ones. The English capitalists whom we sought to interest were incredulous at first, and would not believe that sixteen powerful lights could be operated by one dynamo, certainly not in a single circuit. They thought some trickery was behind it. But they were soon convinced, and the Anglo-American Brush Electric Light Corporation, Limited, was organized to exploit the new industry in England and throughout Europe. The corporation was capitalized at eight hundred thousand pounds, and started a large manufacturing plant in London.

The earliest public lighting in London was that of the Houses of Parliament, Charing Cross Station, Ludgate Hill Station, Blackfriars Bridge, and St. Paul's Churchyard.

The industry experienced a rapid growth during the next two or three years, but was afterward greatly hampered by adverse legislation limiting the electromotive force of lighting circuits. This was thought to be instigated by the gas interests. In the meantime the lights were introduced on the Continent, and also in India, Australia, and other British possessions.

In the early summer of 1882, The Brush Electric Company of Cleveland gave a public exhibition of arc-lamps in the main street of Tokio. It was the first time arc-lights had been seen in Japan, and they excited great interest.

This exhibition was followed by several large contracts with the Japanese government. The first was for lighting the navy-yard and docks at Yokosuka, on the Bay of Tokio, at that time the only navy-yard in Japan. Another was for lighting the Tokio arsenal, where the small arms for the army and navy were manufactured. This contract was made with General (later Field Marshal) Oyama, who was then Minister of War. Another contract was for lighting the government woolen-mills near Tokio, where the cloth for army and navy uniforms was manufactured. Search-lights for the chief vessels of the Japanese navy were also supplied.

In the summer of 1882 the Shanghai Electric Company was organized to light the foreign municipality of Shanghai, China. This was the first central station organized anywhere in the Orient. The Company started with about a hundred arc-lights.

Starting with public-street lighting in Cleveland early in 1879, the central-station idea rapidly took root, and before the end of 1881 lighting stations were in operation in New York, Boston, Philadelphia, Baltimore, Montreal, Cleveland, Buffalo, San Francisco, and several other cities.

Perhaps the largest of the early stations was that of the Brush Electric Light Company of New York, located at 133 and 135 West Twenty-fifth Street. On December 20, 1880, Broadway from Fourteenth to Twenty-sixth street was first lighted from this station, with a circuit nearly two miles in length. Fifteen lamps were used, mounted on ornamental iron poles twenty feet high, and placed at the street intersections. A few weeks later the lights were extended to Thirty-fourth street.

The lights were the ordinary nominal two-thousand-candle power then in vogue; but the lamps gave this amount of light only when measured in the zone of greatest illumination. The average horizontal illumination was about eight hundred candles, and not quite uniformly distributed in all directions.

Not long afterward some of the lights were measured by a famous college professor and patent expert employed by a gas company. Naturally he did not select the most favorable conditions for measurement, and in his report stated that he thought the electric-light company must have arrived at its two-thousand-candle power rating by measuring the lights north, south, east and west, getting five hundred candles each way, and adding all together.

The opposition of the gas companies everywhere was moderate at first, but became strenuous when central-station lighting began to develop, and continued several years.

I argued from the first that the general introduction of arc-lights in cities would greatly stimulate the consumption of gas, on the ground that the public, becoming accustomed to brilliantly lighted streets and stores, would burn far more gas at home. This prediction, paradoxical as it seemed, was abundantly and admittedly fulfilled.

The name of the Telegraph Supply Company was changed in 1881 to the Brush Electric Company, capitalized at three million dollars, a very large corporation for those days.

The forty-light dynamos of 1880 were followed in due time by the sixty-five lighters. Next came the hundred-and-twenty-five-light machines, which long remained the standard Brush arc-dynamos, and came into general use for long-circuit series lighting from central stations.

Almost from the beginning of its commercial success, the Brush Electric Company met with vigorous competition, made practicable by the hostile attitude to all patents manifested by the Federal Courts. Prior to the early eighties it had been the custom of the Courts to sustain almost anything in the shape of a patent, and permit inventors to reissue and claim everything to which they were originally entitled. Doubtless in some cases great injustice was suffered by manufacturers and the public. Then came a sudden reversal of policy, and for about ten years no patents were sustained unless they had previously received favorable action. Inventors in every field of effort suffered from this cause before normal reaction came. In the meanwhile the fundamental patents covering electric lighting had nearly expired by limitation of their terms. All competitors in arc-lighting used the Brush series arc-lamp, more or less modified in appearance. It was indispensable. The most successful used the open-coil dynamo also.

The early success of arc-lighting undoubtedly prompted and hastened the development of incandescence lighting as well as power transmission and electric traction.

Incandescence lighting on a commercial scale came in 1882, about four years after the advent of the arc-light. But its coming had been loudly and continuously proclaimed by the Press for several years, to the great consternation of the gas companies.

In the very early years of electric lighting mine was strictly a "one-man" laboratory. I had no assistant; indeed no assistant was available. I made all the working drawings for the dynamos, lamps and special shop appliances needed. Wrote all the patent specifications. Tested and adjusted all dynamos and lamps. No time was wasted in superfluous sleep or recreation.

I was greatly hampered by the lack of electrical measuring instruments. I had only a Wheatstone bridge and galvanometer. Ammeters and voltmeters were unknown. About 1881 I designed and built a sturdy instrument of each kind for my own shop testing. They were of enormous assistance. I calibrated them by means of storage batteries and resistances of large coils of heavy dynamo magnet wire. The electromotive force of the storage batteries was ascertained by balancing them against "Daniel" batteries of supposed E.M.F. of 1.079 volts. Several hundred of each of these instruments, calibrated by comparison with my first ones, were later supplied to our Central Station plants. They became known as the "meat-scale" instruments.

I also designed an easily-used and reliable dynamometer to measure the driving power required by our dynamos with different loads.

Later, when the Brush Company began the manufacture of electric motors, I designed a perfectly automatic "Prony" brake to measure the power output. It could be set at any desired load, and would maintain that load closely constant as many hours as desired. The ends of the friction pulley were turned inward an inch or two toward the center, thus forming an annular chamber next to the rim of the pulley, into which water was poured from time to time after the motor was started. The water was held in place by centrifugal force, and boiled quietly with an apparently snow-white surface.

We are all familiar with the enormous development of electric lighting which has taken place during the last forty years, since the early days I have referred to.

I thank you for your attention and interest.

Duodecimal System. HENRY LEFFMANN (*Bull. Wagner Free Institute of Science*, 1928, *3*, 3–6) has summarized the advantages of the duodecimal system in a speculative essay. The base of the system is divisible without fractions by 2, 3, 4, and 6. The dozen and the gross are extensively used units in merchandizing. The system is now in use to a limited extent, as is shown by the following examples. The foot is divided into 12 inches, the inch into 12 lines, and the line into 12 points. The year has 12 months; the face of the clock has 12 major divisions; and 12 pence make a shilling. The fathom (6 feet) and the league (3 geographical miles) are really based on a duodecimal system. It is suggested that two new figures or signs be introduced between 9 and 10, that these signs be an inverted J and an inverted V, and that they be designated, respectively, as "kal" and "gan."

J. S. H.

Blast Furnace Slag as a Fertilizer. J. W. WHITE (Pennsylvania State College, School of Agric. and Exp. Station, Bull. 220, 1–19, 1928) has published a preliminary report on the agricultural value of specially prepared blast furnace slag. This slag has hitherto been a by-product of the iron industry of no economic value. It is now marketed in either granular or ground form. The granulated slag is known as agricultural slag and is obtained by running the molten slag into cold water with the production of small, brittle, porous fragments. The ground slag is manufactured from the air-cooled slag by a process of grinding to a fine powder. The slag contains silicates of calcium and magnesium; and its lime and magnesia content ranges between 45 and 50 per cent. It is readily soluble in dilute mineral acids, and acts as a source of calcium for plants and sweetens the soil when used as a fertilizer. Other constituents of the slag may have a stimulating effect on plant growth. In experiments with fourteen crops, thirteen gave greater yields with 20-mesh agricultural slag than with limestone. Granulated slag does not produce yields equal to those produced by limestone. The value of the slag depends on the degree of fineness and the rate of disintegration in the soil. One ton of the slag has been used per acre. In Pennsylvania, the consumption of agricultural lime is only about 20 per cent. of the amount that could be used to advantage. In certain parts of the state, agricultural slag may be available as a cheap source of lime.

J. S. H.

THE PIONEER INVESTIGATIONS ON DYNAMO MACHINES FIFTY YEARS AGO.

BY

ELIHU THOMSON, A.M., Ph.D., LL.D., D.Sc.,

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In looking back over a period of something more than fifty years with an endeavor to picture in some degree the conditions, and especially the electrical status at that time, there are certain salient facts to be noted. Telegraphy over land and by submarine cables had at that time been well established. Deposition of metals, such as copper, in electrotyping, though in use in special instances, was still a comparatively young art, as also in silver plating or plating with a thin blush of gold. Nickel plating, comparatively new as an art, was beginning to grow in favor largely through the work of Weston, who also was early in the field in employing dynamo currents for this work, instead of the more usual Voltaic batteries; mostly of the Smee type.

Dynamo-electric machines, now called electric generators, were rare indeed and of crude design in most cases. The first I ever saw was a Wilde-Ladd machine in the collection of Prof. Robert E. Rogers, later one of our Committee charged with the dynamo tests, in the Department of Physics at the University of Pennsylvania. The recollection of the thrill it gave me to see two men turn the cranks and keep red hot a strip of metal by the current generated is still with me.

There were but two exhibits of dynamo-electric machines at the Centennial Exhibition held in Philadelphia in 1876. In the Machinery Hall was a small space devoted to an exhibit by Gramme of Paris, and another by the Wallace firm, of Ansonia, Connecticut. It is an interesting fact that the Gramme dynamo which figures in the Institute tests of 50 years ago was one of those in the Gramme space at the Centennial Exhibition. I well remember the sign over the Gramme exhibit and the enthusiasm of the French exhibitors or attendants when stating in French several uses of the

Gramme dynamo; "La Lumiere Electrique," "Le Transport de Force," "et la Galvanoplastie." There had been no effort at translation of these terms for the American public. Examples of each of these uses were shown at the exhibit. The electric light was, of course, the carbon arc light in open air in the Gramme space. No other form of electric light source was known as a practical thing at that time, and for some years whenever "the electric light" was referred to, it was the carbon arc light that was meant. Discussion of the subdivision of the electric light meant subdivision of the arc light, necessarily.

"Transport de Force" was illustrated by one Gramme dynamo furnishing electric current energy to another like machine, coupled to the shaft of which latter was a centrifugal water pump which raised water from a tank to a few feet elevation from which it flowed back, producing a waterfall effect, as a pretty illustration of power transmission. Reverse this plant, and magnify it without limit, and you have the modern hydro-electric system, the "white coal" of today. In addition, a special low voltage Gramme machine satisfied the requirements of the plating bath.

My remembrance is that the Wallace-Farmer dynamo at the Centennial Exhibition, driven by a steam engine, was occasionally used, as on special days, for working a single arc light on the roof of such a building as Machinery Hall for illuminating the grounds.

It is well known that the year of the Centennial of 1876, and the Exhibition itself are notable for the first demonstration of the speaking telephone by Alexander Graham Bell. This was the simple magnetic telephone surviving in the telephone receiver of today in universal use, and from which simple electrical device have grown the great telephone systems now existing all over the world.

A little light may be thrown on conditions before the telephone existed when, as I can state from recollection, the whole Western Union telegraph service of Philadelphia city about a year or two before 1870, was concentrated in a single office at the southeast corner of Third and Chestnut Streets. From this office messenger boys were sent out to deliver all over the city the messages received from other

points, while messages to be transmitted to the outside were brought by the sender to the counter in the office itself. I can give this statement a personal touch by relating that I, at the age of about sixteen, spent one of the dreariest nights of my life in lone charge of that office at Third and Chestnut Streets, from dark to dawn. During that whole night there were only two or three messages that were handed to me over the counter for transmission. It was my job to shoot them through a conveyor to the operator's room on the upper floor of the building. The office was finished and furnished in dark wood, and lighted sparsely by poor gas burners, while the office room itself was below the street level several steps. The weight of responsibility was added to that of the surrounding gloom and was very depressing. The street lamps outside at that time were illustrative of positions far apart but not of magnitude. However, it was an experience not soon to be forgotten. How the telephone and electric light have changed all that!

I may be pardoned by referring at this point to my own activities a few years later. In 1874 the Franklin Institute held an industrial exhibition in what was known as the old Pennsylvania Railroad depot at 13th and Market Streets, now the site of the great Wanamaker stores. Market street was traversed by railroad freight cars along a pair of tracks laid on granite sleepers embedded near the street center, from which tracks curved sidings entered the warehouses on the north or south sides of the street. Tandem lines of mules were the motive power for switching the cars to or from the appropriate sidings. This motive power was finally given up, though as a boy in my teens I well remember its operation.

The freight station itself was at 13th and Market, and this, having been rendered vacant, afforded an opportunity for the Franklin Institute 1874 exhibition. Though I was but 21 years of age, I was given the responsibility of a judge of awards in electrical and philosophical instruments. At this time I was teaching science in the Boys' Central High School, the old building at Broad and Green Streets, and was in charge of the chemical laboratory, later being made Professor of Chemistry and Mechanics there in 1876.

The confidence of the Institute was further exemplified in

the request that I should give, in the winter of 1876–77, a course of five lectures in Electricity, a subject in which I had been deeply interested from early boyhood. In these lectures, which were, as usual at the time in such matters, well illustrated by experimental demonstrations, I tried to show that electricity from whatever source, statical, voltaic, dynamical, magneto, etc., was the same in nature, differing only in conditions under which it was manifested. In other words, my general idea was to break down as far as possible what I regarded as unmeaning classifications and distinctions in electrical phenomena which were fundamentally alike if properly regarded; and to make easy the transition from one to the other, both theoretically and practically. Some of the apparatus used was original with me, and constructed by myself. At the present it may seem strange that any proofs of the identity in nature of the various forms of electric manifestation could ever have been needed, but the case was different half a century ago.

I have thus far been reviewing these early events before touching on the real subject matter of the dynamo tests of half a century ago. Perhaps it may serve to bring out a fact that accounts in a way for my being at this time the only survivor of the Committee on Dynamo Electric Machines of the Institute; all of the others were older than I was, and, I regret to say, have long since passed to the "Great Beyond." The men who constituted our Committee were eminent in their time in the various departments of science and engineering and were intimately associated with the activities and management of the Institute itself.

It is, however, a source of intense gratification to me that we can again greet our great pioneer in arc lighting, Mr. Charles F. Brush, of Cleveland, on this platform. Mr. Brush and I were the younger men at the time. Two of his early arc-light dynamos figured in the 1878 tests, one of which was, upon our Committee's recommendation, purchased for the Institute. Mr. Brush has distinguished himself not only in the electric field, but in his many scientific studies. To mention only one other of his pioneer achievements in electricity, we may take the modern storage battery, which has not been changed in any essential respect since his work

of invention and development, more than forty-five years ago.

Fifty years ago there were, of course, no electric supply stations and no ready means for securing electric currents for demonstrations, as for working an electric light with the carbon arc. Dynamos were few and far between. Instead, it was necessary to set up a series of fifty or sixty Grove or Bunsen cells for the purpose. This was a heavy task in itself, and to take them down after an hour or two of use, a worse one, demanding exposure to irritating fumes of nitrogen tetroxide, without gas masks, and involved the handling of large amounts of strong acids. I know well what this meant from actual experience in those early days. How easy it is now to tap the electric supply circuit and secure the electric energy needed for any purpose!

When, about 1877, the Institute had established in this hall a steam engine of about 6 horse-power for driving forms of machinery to be brought to the attention of the Institute, it was natural that attention should be turned to the acquisition of an electric current source. The age of electric applications was just beginning and the electric arc-light was far more convenient than the calcium or lime-light for such purposes as lantern projection. It was, therefore, determined that a dynamo suitable for the then present and prospective needs of the Institute be purchased. It was thought also that a general service might be rendered if tests could be conducted which might, at least in a general way, determine the electrical and mechanical properties of such machines, and also their applicability to the production of light in the use of the carbon arc as a source.

We are here to commemorate the fiftieth anniversary year of the series of tests made by the Institute Committee on Dynamo Electric Machines, the Report of which Committee was published in the JOURNAL of the Institute for May and June, 1878.

While, before this report was made, there were in existence some data on the power consumed by dynamos working single arc-lamps as used in a few lighthouses, and determinations of the candle power of the light produced (with similar sporadic tests), it has appeared that the Franklin Institute tests

constitute the first real investigations, comparative in nature for different machines, and complete enough to enable one to judge of the machines as more or less efficient converters of mechanical into electrical energy. The report was probably unique in the inclusion of electrical measurements as a special feature.

This part of the work was confided to Prof. Edwin J. Houston and myself as a sub-committee. The paucity of instruments suitable for such measures, and indeed the entire absence of such means, made it necessary to improvise to an extent quite inconceivable in these days. This condition of lack of instruments and standards remained acute even for a considerable number of years subsequent to 1878.

The unit of current in use was called the "Veber" or "Weber." Not till the International Conferences of 1881 in Paris was the name Ampère adopted for the unit of current. We already had the Volt and Ohm as international units and approximate standards.

In our report of losses in the machines tested, we designated as due to *local action*, power which disappeared in a machine and which could not be accounted for in the electric arc or any part of the electric circuit of the dynamo. In subsequent years it was found to be due to two causes, now well known as eddy current loss and magnetic hysteresis.

Fifty years ago, little was known of the waste of energy in changes of magnetism of iron now called hysteresis.

The tests clearly disclosed I believe for the first time that the measured resistance of arcs was, other conditions being the same, nearly in the inverse proportion to the current in the arc: an unstable load requiring that the machines, to maintain steady arcs, must have what was long after known as drooping characteristics, the characteristic being a curve showing the relation between the current in a series machine and its voltage or E.M.F.

Beyond a certain value of current generated the E.M.F. at the terminals of the dynamo must decrease as the current further increases and at a certain rate, so that the current becomes stable, without surges.

Another matter also brought out was that the internal resistance of the machine itself should be as low as possible

while the work resistance should be high in relation thereto, in order to secure the best efficiency in electrical energy output in relation to mechanical input.

These conditions are all so plain today that they seem self evident, but it took some years after the test for their significance to be generally understood.

The report itself reveals many of the particulars of operation not fully understood before.

It was in this hall that our Committee made the investigations which were embodied in the Report of May and June, 1878. As both Professor Houston and I were engaged in teaching at the Boys' Central High School for most of the day, and the tests had to be conducted after hours, so to speak, it will be seen that those were strenuous days of fifty years ago.

There is an acknowledgment I would like to make at this time as it may supplement to some extent at least, an unintentional omission in my address delivered with the history of the Institute given by me upon the occasion of its Hundredth Anniversary.

Prof. Monroe B. Snyder, who, fifty years ago, was in charge of the Astronomical Observatory at the Boys' Central High School, was much interested in the proposed dynamo tests of 1877–78, and discussed with me the methods to be pursued. His help and suggestions were of considerable value in the outlining of the work of our electrical tests. He followed closely in succeeding years the progress abroad in establishing the electrical units on a firm basis. At the time of the Electrical Exhibition in 1884, the first of its kind in America, and conducted as a Franklin Institute enterprise, he prepared an address on "The Establishment of a National Bureau of Physical Standards" for the Electrical Conferences held in Philadelphia in connection with the Exhibition of 1884.

Prof. Snyder's early address, with one of Lord Kelvin's, I believe, were the ones presented to the Senate Committee of 1900, which resulted in the establishment of the Bureau of Standards in Washington, the activities of which now cover so large a field. I regret that these facts were not presented in my historical review at the time of the Centenary of the

Institute, as they serve to connect the Institute with one of the major developments in science in our country, and to show that Prof. Snyder was early awake to the necessities of the case. Prof. Snyder, now over eighty, is still with us and still looking forward to the new advances.

During the half century since the time we are commemorating, there has been a vast development in many fields of science and industry, but the progress in the understanding of electricity, the great strides in its application, the enormous expansion of industries based on electricity, have been so phenomenal, that it is difficult to imagine that any future period can ever present such a record of achievement.

In that period there has been verified the idea that, after all, electrical actions, those of the electrons, are fundamental in explaining the relations between the different forms of matter themselves, and to energy.

Thirty years ago in a paper before the Franklin Institute, I ventured to suggest that we might come to regard all actions, even mechanical properties, as in their essence electrical. The criticism by one electrical journal was that it was natural that an electrician should wish to make all things electrical. But history has answered the question, and furnished the proof, as we now know. We accomplish unification, and to that extent simplification, but I think that there will always remain, in the growth of knowledge, more than we can ever explain.

By careful investigation and tests, such as those made fifty years ago, we acquire a basis for progress and, assisted by imagination, we are able to project our thoughts into new and fruitful fields. I remember saying to some younger men, after we had been working with so-called direct currents and had begun work in the alternating current field that the field offered by electricity in vibration would be boundless. In 1881 I had observed some curious high frequency phenomena, and in 1889 constructed probably the first high frequency dynamo made, and this was followed up in the next decade with numerous experiments in that novel field, by Mr. Tesla and myself.

We see in radio actual applications on the widest scale

of these early results, such that the schoolboy may talk of kilocycles, radio frequency, audio-frequency, inductance, capacity and the like terms, in the new electric art. Let us hope that he is real student enough to learn just what they mean.

Can we doubt that the future will have in store for mankind many triumphs following the earnest application of the scientific method? This may be succinctly expressed in the words "Prove all things and hold fast to that which is good."

When I prepared the foregoing statements I was unaware that we should be favored with the presence at these exercises of so many who have been identified with electrical progress within the period of years since 1878.

As a representative of these I may mention my coworker since the early days when at the time of the tests he was yet a pupil of mine at the Boys' Central High School and one of the most promising, Dr. E. W. Rice, Jr. Also Dr. Frank J. Sprague whose pioneer work in the development of electric railways did so much to establish the electric motor as the power for traction. I first met him as an exhibitor at The Franklin Institute Electrical Exhibition of 1884 as I clearly remember. He hasn't much changed since then.

What Becomes of Stellar Radiation? BOHUSLAV BRAUNER and J. H. JEANS. (*Nature*, April 28, 1928.) Sir Oliver Lodge has asked "What becomes of the radiation which the stars are continually pouring into space?" Professor Brauner of Prague comments thus: In view of the consequences of Einstein's theory of relativity "to-day space must be regarded as finite. If a straight line starts from a star it does not go straight to infinity, but returns to the original source. I beg to conjecture or suggest that the radiation from the star may behave like the straight line and be brought back to its origin again, after having travelled around the universe." For this journey Jeans allows 10^{11} years, but, the stars being calculated to be much older than this, a sufficient time has elapsed for at least the earlier part of their radiation to have made the trip and returned to the source, unless it was intercepted by other stars on the way.

Jeans agrees that light can "travel round and round in an Einstein universe," though not in the universe according to de Sitter. While admitting that some part of the radiation emitted by a star does re-enter it after the journey around the universe, he holds the fraction to be very small. "If it were nearly unity we should see a star in every direction in space, and the sky would be a uniform blaze of light. If even one part in 100,000 of their light fell back into the stars, the night would be half as bright as the day."

Jeans does not share the difficulty felt by Lodge and Brauner as to the fate of radiation, since the annihilation of all the matter in the universe would raise the temperature of space only about 11.5° C. "Space is so vast by comparison with the matter it contains, that discussing the ultimate fate of radiation seems rather like discussing the ultimate fate of a few lumps of sugar dropped into the Atlantic." He sees much difficulty in believing that stellar radiation can create new matter. The amount of energy requisite to produce a hydrogen atom is .0015 erg. To emit a quantum having so much energy a temperature of about 75×10^{11} degrees would be needed.

G. F. S.

RECENT PROGRESS IN THE THEORY OF BAND SPECTRA.*

BY

EDWIN C. KEMBLE, Ph.D.,

Jefferson Physical Laboratory, Harvard University.

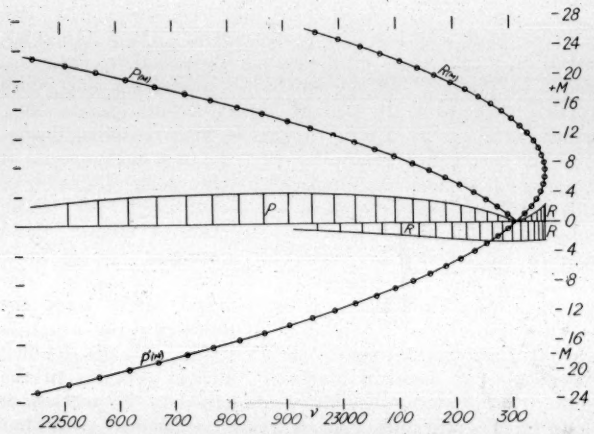
GASEOUS spectra are divided into two classes which we conventionally call line and band spectra. These names are based on a difference in appearance illustrated by Figures *a* and *b* of Plate I, but are somewhat misleading since both types of spectrum are seen to consist of fine discrete lines, when examined by a spectroscope of high resolving power. The line spectrum is really the spectrum of a single species of atom or of a monatomic molecule. The study of spectra of this type has been the most important single key to the solution of the problem of the structure of atoms. Band spectra are emitted by molecules containing two or more atoms and hence we frequently (and more accurately) refer to them as "molecular spectra." Their study is of the greatest importance in helping us to understand the structure of molecules, the nature of valence forces, and the detailed mechanism of chemical reactions. Recent progress in the application of wave or quantum mechanics to the problem of band spectra and molecular structure has been so great that it seems not chimerical to hope that in a few years we may understand the fundamental principles of molecular formation as definitely as we now understand the principles of dynamo design. If this hope is realized only mathematical difficulties will prevent us from making a deductive science of chemistry. Unfortunately, however, there is little prospect that the mathematical difficulties will be overcome in any wholesale manner.

Thus far the study of band spectra has been largely confined to a consideration of those originating in diatomic molecules since the spectra of more complicated species are so complex that they are of little use. Even the diatomic bands are discouragingly complex in many cases as will be

* Presented at a meeting held Thursday, March 29, 1928.

evident from such a "close-up" as Fig. *d*, Plate I. A simpler example is shown in Fig. *e*, Plate I. The lines in the left hand portion of this figure are evidently arranged in a regular manner in two overlapping series. This regular structure is conveniently brought out by making a plot, or Fortrat diagram, such as that shown in Fig. 1. Here the abscissas

FIG. 1.



Fortrat diagram for λ 4280 CuH band. From Chapter IV of Report on Molecular Spectra in Gases (Bull. National Research Council No. 57, 1926).

are the line frequencies, or reciprocal wave-lengths, and the ordinates are the ordinal numbers of the lines in the series to which they belong. Fig. 2 shows a similar diagram for a more complicated case.

In the spectrum of an individual molecular species we have, of course, not one band such as those just discussed, but many. These are arranged in a regular manner in groups or systems (Fig. *b* and *f*, Plate I) and there may be many systems in the complete spectrum of a molecule. Thus the molecular spectrum may be regarded as organized according to the following plan, or hierarchy:

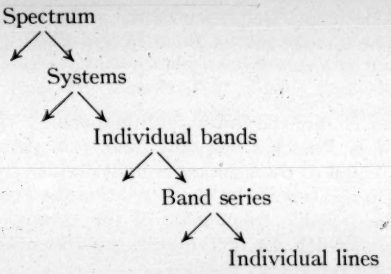
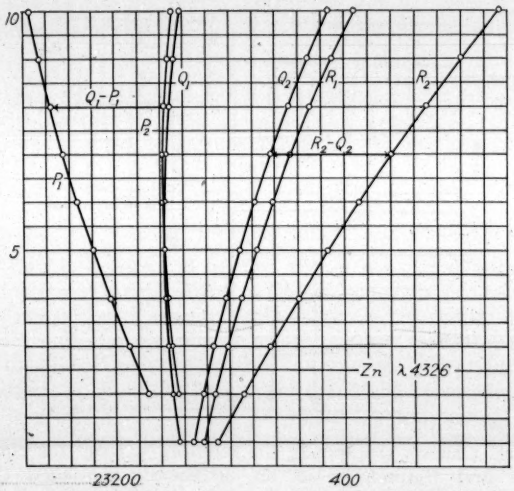


FIG. 2.



Fortrat diagram for λ 4326 ZnH band. From Hulthén's thesis, Lund, 1923.

According to our present conception of things the energies of atoms and molecules are not continuously variable but are restricted to certain discrete values or energy levels. The emission of radiation occurs only as an accompaniment to a discontinuous jump from one such energy level to another,

the wave-length and frequency of the radiation being determined by the famous rule of Einstein and Bohr:

$$E' - E'' = h\nu.$$

Here E' and E'' are the initial and final energy values of the molecule, h is Planck's constant, and ν is the vibrational frequency (equal to the velocity of light divided by the wave-length). On account of the above relation the possible values of E fix the possible frequencies of the spectrum and conversely the frequencies determined experimentally may be used to locate the energy levels.

FIG. 3.

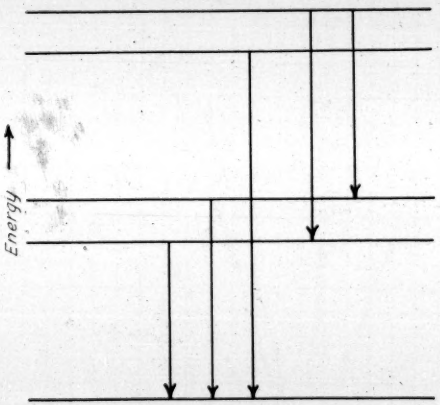
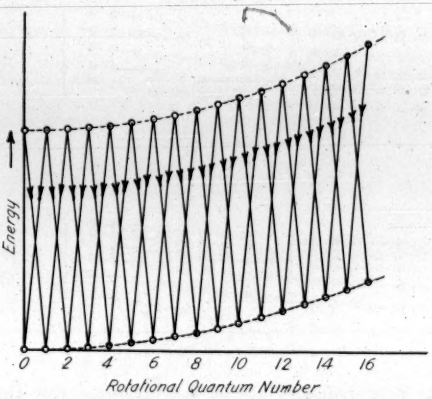


Fig. 3 shows graphically the relation between the energy levels and frequencies in an artificially simplified case. Energy is plotted vertically, the horizontal lines being energy levels. The vertical lines show the jumps which produce the different wave-lengths in the spectrum. The lengths of these lines are proportional to the radiation frequencies and inversely proportional to the wave-lengths.

The system of energy values of a molecule may be worked out from its spectrum in many cases and is both more simple

and more fundamental than the spectrum itself. The location of the energy levels is the fundamental problem of the spectroscopist. There are many energy values for any molecule but fortunately they are organized in a way that parallels the organization of the spectrum itself. Fig. 4 shows a small

FIG. 4.

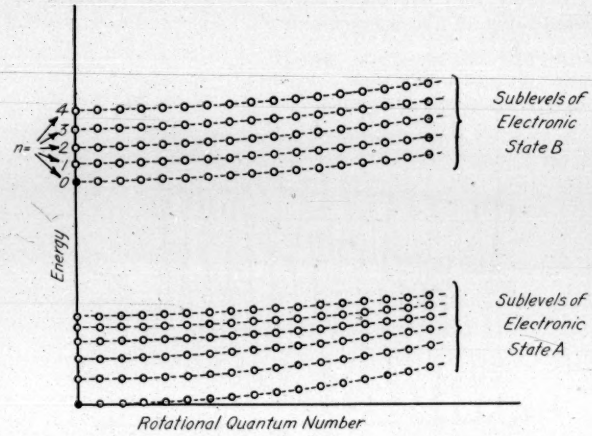


part of the system of energy values associated with the production of a single band of the simplest type. There are here two series of energy levels and to avoid confusion the energy is plotted as ordinate against a series ordinal number or "rotational quantum number" as abscissa. The lines with arrow heads show the jumps which actually occur and lead to spectrum lines. It will be observed that owing to a "principle of selection" only a few of the very large number of possible transitions actually take place.

Fig. 5 illustrates in a general way the organization of the complete system of energy levels of a molecule as empirically determined. There are many such series as shown in Fig. 4 and these are organized into series of series. The numbers n in the figure are the ordinal numbers of successive members of one of these superseries. It should be understood that the diagram is simplified by the artificial termination of both

types of series and by the omission of minor complications which frequently occur.

FIG. 5.

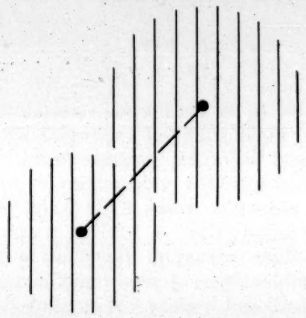


Let us now consider for a few minutes the theoretical interpretation of the empirical energy level scheme. A qualitatively satisfactory interpretation was first worked out on the basis of the classical quantum theory of Bohr and Sommerfeld. In this theory it was assumed *first* that the motions of the parts of the atom or molecule in any given energy state take place approximately in accordance with the laws of classical mechanics; *second* that the motion is always a combination of periodic motions like the motion of a point on the earth's surface resulting from the annual rotation of the earth about the sun, the monthly rotation of the earth and moon about their center of gravity, and the daily revolution of the earth about its own axis; *third* that among all the possible motions permitted by the classical mechanics only those actually occur which satisfy certain mathematical rules or "quantum conditions" which relate the spacing of the energy values to the periods of the motion. These rules like nearly all fundamental laws in physics are devised to fit the experi-

mental facts and are justified only through the large number of such facts which they correlate. I will not bore you with their mathematical formulation but will content myself with a brief description of the way in which they work out when applied to a diatomic molecule.

Our atomic model, as you all know, consists of a heavy central positively charged nucleus around which moves a swarm of from one to ninety-two electrons with motions at least approximating those of planets. The diatomic molecule we assume to consist of a pair of such atoms held together by forces which vary with the distance between the nuclei in

FIG. 6.



such a way that atoms may vibrate back and forth along the center line as well as rotate about the center of gravity. The energy of such a molecule may be arbitrarily divided into three parts as follows: First there is the energy which the molecule would have if the nuclei were neither vibrating nor rotating. This energy has relatively widely spaced discrete values determined primarily by the frequencies of the orbital motions of the electrons. Then there is the energy of vibration of a molecule which is not rotating. The spacing of the vibrational energy values is proportional to the vibrational frequency and is normally smaller than the spacing of the electronic energy levels. When the spacing of these levels is measured experimentally we can determine from it the frequency of vibration and so obtain information regarding the

law of force for the attraction and repulsion of the atoms in the neighborhood of their equilibrium point. This varies from one electronic energy level or electronic state to another. Finally there is the rotational energy which also has discrete values but with a still smaller spacing than the vibrational energy values. The rotational energy values are determined by the moment of inertia of the molecule and from their experimentally measured spacing we may discover the moments of inertia of the molecules in their various electronic and vibrational states. In particular we may discover the moment of inertia of the non-vibrating molecule which is related to the atomic masses m_1 and m_2 and to their equilibrium separation r_0 by the formula

$$I_0 = \left(\frac{m_1 m_2}{m_1 + m_2}\right) r_0^2.$$

Thus it is possible to fix the normal internuclear distances of the various electronic states of molecules with considerable precision by band spectrum measurements. We obtain in this way, for example, the value 2.663×10^{-8} cm. for the normal iodine molecule, 3.015×10^{-8} cm. for one of the excited states of iodine, 1.279×10^{-8} cm. for normal HCl, etc.[1]

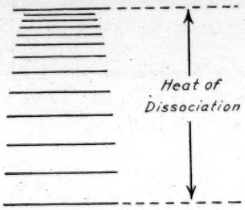
The energy values plotted on Fig. 5 are of course made up by various combinations of electronic energy, vibrational energy, and rotational energy. The dotted lines connect levels having a common electronic and vibrational energy but differing in rotational energy. From the spacing of the levels in one of these series we determine the moment of inertia and the mean distance between the nuclei. The lower group of energy levels is associated with a single electronic state A, the upper with another electronic state B. The different series in, say, the upper group differ in vibrational energy and the spacing of the levels indicated by circles on the vertical axis is a measure of the frequency of vibration of the molecule in the electronic state B. The lower left hand level in each

[1] A summary of the molecular constants derived from band spectra is given in Section 7 of the chapter on "Electronic Bands" by Birge in the Report on Molecular Spectra in Gases issued by the National Research Council (Bulletin No. 57, Dec. 1926). A longer and more complete table also prepared by Birge will appear shortly in the International Critical Tables.

group (solid circle) corresponds to a molecular state in which the vibrational and rotational energies are very nearly zero. The spacing of these levels is the difference in the electronic energies of states A and B.

The values of the fundamental constants of the molecule determined from the band spectrum may be checked in other ways such as by the measurement of the specific heats and free energies of gases,[2] but no other method is as precise as the spectroscopic one where the latter is available. It is also possible to determine spectroscopically the magnetic moments and gyroscopic properties of the molecules but there is not time here for a discussion of this detail.

FIG. 7.



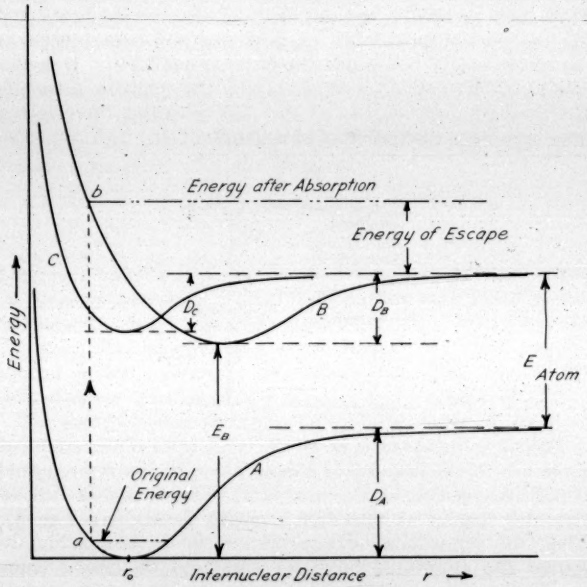
Of major importance, however, is the optical measurement of the heat of dissociation of a molecule or the energy required to pull its constituent atoms apart.[3] This energy is tied up with the system of vibrational energy levels (see Fig. 7). When the vibrational energy of a molecule is steadily increased the amplitude increases also, and the atoms come nearer and nearer to escaping from each other at the end of the out swing. As disruption approaches the period of vibration becomes very long. The spacing of the vibrational levels accordingly approaches zero as the energy of vibration approaches the heat of dissociation as a limit. A graph of the vibrational energy values has therefore the appearance indicated in Fig. 7 and the heat of dissociation may be read off

[2] Cf. for example, D. M. Dennison, *Proc. Roy. Soc.*, **A-115**, 484 (1927); Hicks and Mitchell, *J. Am. Chem. Soc.*, **48**, 1520 (1926).

[3] Cf. Birge and Sponer, *Phys. Rev.*, **28**, 259 (1926); H. Sponer, Ergebnisse der Exakten Wissenschaften, Bd. **6**, 75 (1927).

from it directly if the energies have been fully determined by experiment. Usually complete data are not available but even then we may frequently locate the convergence point of the energy level scheme approximately by a process of extrapolation.

FIG. 8.



Having measured the normal internuclear spacing, the frequency of vibration, and the energy of dissociation of an electronic state we are in a position to draw up a good approximate curve for the mutual energy of the two atoms as a function of the distance between them. This curve has normally the general appearance of the three shown in Fig. 8. Its slope gives the force of attraction or repulsion between the atoms. At large distances it has a small positive slope asso-

[4] J. Franck, *Trans. Faraday Soc.*, 21, 3, 1925.

ciated with an attractive force, while at sufficiently small distances the force must be repulsive and the slope negative. The minimum point locates the equilibrium value of r and may be determined from the moment of inertia. The curvature near this point fixes the frequency of vibration for small amplitudes and may be determined experimentally from the vibrational energy scheme. The heat of dissociation locates a horizontal asymptote to the curve for infinite r while the axis of ordinates constitutes a vertical asymptote for zero r. For the rest we know from the regularity of the spacing of the vibrational energy levels that the curve is normally smooth. Hence a clever draughtsman can draw in a pretty good approximation to the mutual energy curve on the basis of the elementary measurements I have sketched. A more detailed analysis of the experimental data will, of course, make possible a more accurate curve involving less guesswork. Fig. 8 shows three such curves for three possible electronic states of a molecule. Each has its own moment of inertia, frequency of vibration, and heat of dissociation.

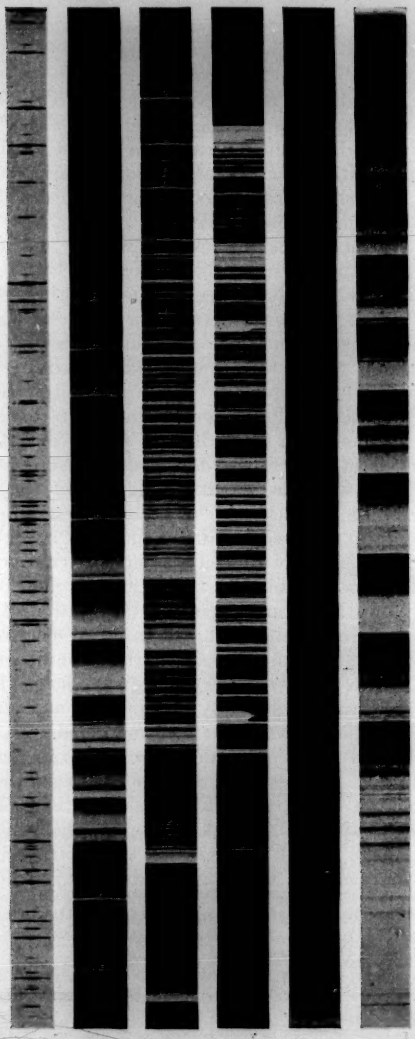
This figure is also adapted to the explanation of the mechanism of photochemical dissociation suggested a short time ago by Professor Franck of the University of Göttingen.* His suggestion is based on the fact that light quanta or photons are very light and move very rapidly. On account of their small momentum they cannot appreciably affect the momentum or kinetic energy of the heavy nuclei. Moreover they are apparently absorbed so quickly that the process is all over before the nuclei have moved any appreciable distance from their initial positions. The molecule can dissociate only if it receives an amount of nuclear vibrational energy greater than the energy of dissociation and it follows from the above considerations that the action of photons in producing dissociation must be *indirect*. Fig. 8 shows how it may be done. We suppose that the molecule is initially in the lowest electronic state A where it vibrates back and forth with a certain small initial vibrational energy. The impact of a light quantum (or of an electron) may now at any moment raise it straight upward to a point on one of the curves B or C. This

* Joint winner with Professor Gust. Hertz of the Nobel Prize for Physics for 1925.

change corresponds to a shift in the electronic energy with unaltered internuclear distance. The nuclear kinetic energy will be unchanged and the final energy will be approximately the sum of the initial kinetic energy and the final potential energy (or mutual electronic energy). Thus if caught at the point *a* it may be carried up to the point *b*, the initial and final kinetic energies being in this case zero. After absorption we have still a molecule, but the latter is left, so to speak, "on the side of a hill" and slides down past the equilibrium point and up over the opposite slope to return no more. In other words the repulsive force and mutual energy of the atoms at *b* is so great that they are torn apart despite their mutual attraction at large distances and separate with a residual kinetic energy marked "energy of escape" on the figure. This theory of optical dissociation fits the observed facts very well and seems to be one of the most important recent contributions from physics to photochemical theory.

In conclusion I should like to tell you a little something about the wave or quantum mechanics and the new light which it has shed on the problem of molecular structure. In the time available I can hope to give you only rather vague ideas, but perhaps they will be worth while. This new mechanics is, I think, more revolutionary than Einstein's doctrine of relativity. It certainly is more important from most points of view than that justly famous theory. The quantum mechanics was developed because the Bohr theory despite many initial successes proved on close examination inadequate to account fully for the experimental facts. It accounted approximately for the energy level schemes of atoms and molecules, but failed quantitatively in this domain of its greatest success besides failing completely to answer questions about refraction, collisions, and other aperiodic phenomena. To mention an important specific instance, the Bohr theory proved inadequate to account for the formation of non-ionic molecules. These molecules are apparently held together by some sort of pairing of valence electrons belonging to two atoms. The attempt to translate the static atom theories of Lewis and Langmuir into the dynamical language of Bohr leads to the assumption of valence electrons shared in such a way that they revolve in orbits either enclosing both

PLATE I.



a. Line spectrum of Argon (negative).
b. Silicon Nitride band system λ 4000 to λ 4800. Moderate dispersion spectrogram by Mulliken (positive).
c. λ 4216 group of violet CN band system. Spectrogram by Mulliken (positive).
d. High dispersion spectrogram of λ 6544 band of First Positive Nitrogen Group (N_2) by Birge (positive). [Report on Molecular Spectra, frontispiece (*h*)].
e. High dispersion spectrogram of λ 3040 band of the β system of NO. (Mulliken) (negative).
f. 'A' system of copper iodide bands. Moderate dispersion spectrogram by Mulliken (negative).

nuclei or located in a plane perpendicular to the molecular axis and midway between the nuclei. In either case the process of dissociation in the case of a symmetrical molecule would lead inevitably to a break at some point corresponding to a shift from shared orbits to unshared orbits. The study of the vibrational energy levels of symmetrical molecules shows no evidence for such a break, however, and it is highly improbable that anything of the sort exists.

Happily this difficulty along with many others disappears when we adopt the wave mechanics point of view. The fundamental thing about this new point of view as I see it is the recognition of the fact that the dual nature of light as both waves and corpuscles is a universal situation. Light apparently consists of bundles or corpuscles of energy which move as if guided from place to place by waves. To predict the behaviour of the corpuscles we must first solve a wave equation to see what the waves will do. Then the statistical behaviour of the corpuscles is to be determined by the fact that the corpuscular energy at any point is on the average equal to the intensity of the wave system at that point. We know nothing more than this statistical behaviour of the corpuscles. Now the recent experimental work of Davisson [5] and his collaborators shows that a beam of electrons is diffracted by a crystal in almost exactly the same way as a beam of X-rays, which are merely very short wave-length light rays. Thus electrons and presumably also protons and atoms have the characteristics of waves as well as of particles. Apparently all known kinds of particles are simultaneously waves and corpuscles. The essential difference between the electron and the photon lies in the differential equations of the two types of wave system. Thanks to de Broglie [6] and Schrödinger [7] we have found out how to set up the differential equation for electron waves and have discovered that it

[5] Davisson and Kunsman, *Phys. Rev.*, **22**, 242 (1925); Davisson and Germer, *Phys. Rev.*, **30**, 705 (1927); C. J. Davisson, J. FRANKLIN INST., **205**, 597 (1928).

[6] L. de Broglie, *Annales de Physique* (10), **3**, 22 (1925).

[7] E. Schrödinger, *Annalen der Physik*, **79**, 361 and 489 (1926). *Phys. Rev.*, **28**, 1049 (1926). The statistical interpretation of Schrödinger's theory which lies behind the Dirac-Jordan transformation theory form of the quantum mechanics and the Heisenberg principle of indeterminateness was first stated by Born, *Zeits. f. Phys.*, **38**, 803 (1926).

yields results in agreement with ordinary mechanics for large scale phenomena though the results are different for atomic and molecular problems.

The attack on the problem of atomic mechanics now becomes essentially the same as the attack on a problem in the propagation of photons. We first set up the differential equation for the wave-phenomenon which parallels the corpuscular phenomenon (a physical analogue of psychophysical parallelism!). We solve this problem subject to certain boundary conditions and obtain first of all a set of discrete wave frequencies like the frequencies of vibration of a stretched string. These frequencies multiplied by Planck's constant give us the experimental energy level system of the atom or molecule. We also get a definite wave-system for each energy level whose intensity we believe determines the statistical behaviour of the electrons or other particles which make up the system. Concerning the finer details of the electronic motion we know as little as we know about the details of the motion of photons, i.e., exactly nothing.

Let me illustrate. The simplest atom is that of hydrogen, which consists of a single electron revolving about a heavy positive nucleus. Its energy level scheme was given correctly * by the Bohr theory and is given correctly by the wave mechanics. According to the former theory every energy level is associated with a definite type of circular or elliptic orbit. According to the new quantum mechanics it is associated with a system of standing waves having the nucleus as its center. In the case of the normal state the wave-system is spherically symmetric without nodes. In all cases it extends to infinity in all directions but drops off very rapidly in intensity outside a sphere of radius equal to the aphelion distance in the corresponding Bohr orbit. We interpret the infinite extent of the wave system to mean that the electron occasionally makes very long excursions from home, there being no limit to the length of these excursions.

Applied to the vibrational and rotational motion of a diatomic molecule the wave mechanics gives essentially the same energy levels as the Bohr theory and allows us to

* The fine structure is not quite right if the calculation is made on the basis of a model including an electron spin.

retain our previous interpretation of the spacing of these levels practically unchanged. The greatest success of the new theory, however, is in its application to the problem of molecule formation. There is no longer any difficulty about the breaking of orbits due to the separation of the atoms in a non-ionic molecule, for the fragile glass-like orbits of the Bohr theory are replaced by the plastic solutions of a partial differential equation. Consider the hydrogen case which has been studied in some detail. If two normal hydrogen atoms approach each other their wave-systems overlap and an interference phenomenon is set up much like the interference of light from two apertures in Young's experiment. This interference between the wave-systems alters the vibration frequency and energy in a way which varies with the distance between the nuclei and gives us a mutual energy curve in essential agreement with that which the band spectrum of hydrogen has revealed.[8] The results (see table) are not perfect since the solution of the wave equation is a difficult mathematical problem for which we have as yet but a first approximation. The agreement is satisfactory, however, in view of the approximations involved and taken with the many other successes of the theory warrants us in regarding the problem of the formation of the hydrogen molecule as solved in principle. We have every expectation that these results are capable of being generalized to apply to other types of molecule. Apparently the pairing of valence electrons noted so long ago by the chemists is an interference phenomenon.

TABLE OF CONSTANTS FOR NORMAL HYDROGEN MOLECULE.

	r_0 (10^{-8} cm.).	D (volts).	ν_0 (cm.$^{-1}$).
Computed (Sugiura)	0.80	3.2	4800
Computed (Wang)	0.74	3.8	4900
Observed	0.75	4.4	4360

ν_0 denotes the vibrational frequency for an infinitesimal amplitude in wave-number units.

[8] Heitler and London, *Zeits. f. Phys.*, **44**, 455 (1927); Sugiura, *Zeits. f. Phys.*, **45**, 484 (1927); S. C. Wang, *Phys. Rev.*, **31**, 579, 1928.

PROBE MEASUREMENTS IN THE NORMAL ELECTRIC ARC.

BY

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BARTOL RESEARCH Foundation Communication No. 25.

Abstract. Probe measurements have been made in cadmium, thallium and carbon arcs by sweeping the probe through the arc at a constant velocity and measuring the current collected by the throw on a ballistic galvanometer with different probe potentials applied. The voltage-current characteristic was analyzed to get a measure of the positive ion concentration, the average electron temperature and the space potential by the Langmuir method. The cathode falls found were each equal to, or only slightly higher than, the ionization potential of the active gas, and were 9.0 volts in the cadmium arc, 6.5 volts in the thallium arc and 5.0 volts in the carbon arc. The last value is to be compared with the ionization potential of the cyanogen molecule of 4.4 volts. The anode fall found in the carbon arc was 16.5 volts. These values for the carbon arc agree almost exactly with the "forward" and "back" E.M.F.s measured by Duddell and others at the cathode and the anode but not identified by them as the cathode and anode falls. The electron velocities were found to be Maxwellian with average velocities sufficiently high to account for the ionization known to exist. Over parts of the arc stream where the fields were found to be large the electrons showed corresponding increases in average temperature and evidence that only about three-quarters of the energy gained by the electrons from the field between collisions is lost by the lectrons while the remaining quarter is retained and made evident by the steady increase in the electron temperture. As the current flowing through the arc was increased, the radiation per unit volume and also the positive ion current per unit length of the probe were found to increase very rapidly indicating an increase in the efficiency of the ionization process as the current increases. It is thought that this observation is closely related to the fact that the voltage drop across the arc decreases as the arc current increases.

THE Langmuir probe method of determining the electronic energy distribution and the positive ion concentration in low pressure arc discharges, has been used to explore certain normal arcs operating at atmospheric pressure. The new facts concerning the detailed mechanism of the electric arc which were revealed by these probe measurements seem to be of sufficient importance to warrant this advance report being made before the entire project has been completed. More extensive explorations of a number of different arcs are now being prepared, the results of which will also be published in this JOURNAL.

THE LANGMUIR PROBE METHOD.

The theory of the use of probes for measuring space potentials, electron energies, etc., has been presented in a series of papers by Langmuir and Mott-Smith [1] along with examples of experimental results. Although the details of procedure were a little different in the case at hand, the general method was the same as that developed by the above writers and can be outlined as follows.

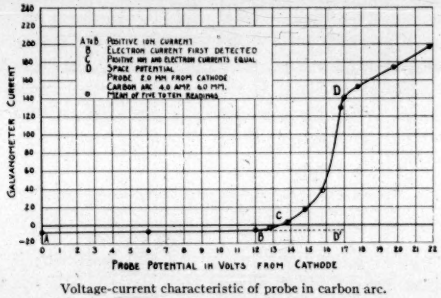
The direct current arc is usually operated by power furnished the electrodes from a battery or generator through a suitable resistance which stabilizes the discharge at the preassigned current flow. The potential drop over the arc, measured at the electrodes, is usually thought of as being divided into three parts, namely, (1) the cathode fall very close to the negative electrode surface, (2) the arc stream fall in potential supposedly distributed uniformly along the arc stream, and (3) the anode fall at the surface of the positive electrode. Thus the potential of the space at any given distance from one of the electrodes, for instance, the cathode, is made up of the cathode fall plus that part of the arc stream fall between the point in question and the cathode. In order to measure this space potential it is not sufficient simply to immerse the probe in the discharge and measure its potential by means of an electrometer or a high resistance voltmeter. The result can only be gotten in the more indirect way of studying the voltage-current characteristic of the probe when it is immersed in the discharge and maintained at definite potentials with respect to one of the electrodes by means of a battery. The potential of the cathode will be taken arbitrarily as zero and a current of positive charges coming to the probe will be called a negative current in order to be consistent with the accepted practice. If the probe potential is negative with respect to the space, a positive ion sheath will form around the probe. Within this sheath perfect reflection will take place of all the electrons which enter it with insufficient velocity to penetrate to the probe against the adverse field set up, due to the charge maintained on the probe by the battery. Positive ions which happen to enter the sheath find themselves in a field of force which carries them through the

[1] *G. E. Rev.*, 27, 449, 538, 616, 762, 810 (1924).

sheath to the probe and the rate at which these ions come to the probe is indicated by the current flowing in the probe circuit.

This positive ion current, AB of Fig. 1, is seen to change very little as the probe potential changes. What change there is observed is due to the change in the surface area of the sheath as the probe potential is altered. When the probe is slightly negative with respect to the space, enough fast electrons are able to penetrate the sheath and strike the probe to give an electron current large enough to be measured, superimposed on the positive ion current. This point is indicated by B in Fig. 1. At C on the same curve, the electron

FIG. 1.



Voltage-current characteristic of probe in carbon arc.

current exactly equals the positive ion current making the total current registered in the probe circuit zero, and thus showing the potential which would be found if the probe were connected to a high resistance voltmeter and allowed to "float." At potentials higher than C the electron current exceeds the positive ion current. If it happens that the electrons which come to the probe have a Maxwellian distribution of velocities, a plot of the ordinates representing the difference between the curves BCD and BD' on semi-logarithmic paper will give the average temperature of the electrons because of the well known relationship

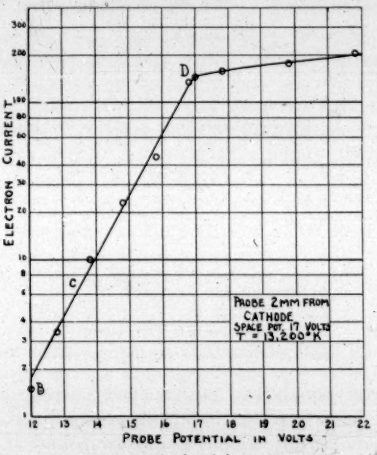
$$i = a\epsilon^{\frac{eV}{kT}} \qquad (1)$$

which applies to this case. Since

$$\log_e i = \frac{e}{kT} V + \log_e a, \qquad (2)$$

the slope of the straight line part of the curve *BCD* of Fig. 2 must be e/kT and with e/k known ($e = 4.774 \times 10^{-10}$ e.s.u. and $k = 1.372 \times 10^{-16}$ ergs per degree) the temperature T can be calculated. The theory of the Langmuir probe method predicts that the "current-voltage" characteristic will show

FIG. 2.



Semi-logarithmic plot of electron current.

a change in slope when the probe potential equals the space potential. It is on this basis that the bend of the curve at *D* in Fig. 2 is taken as an indication of the true potential of the space.

Probe measurements following the general method described above have been successfully carried out in low pressure discharges with the probe continually immersed in the discharge space. Such a procedure is not possible in the high pressure arc because the bombardment of the probe is so

violent that it soon heats up to the melting point or else it becomes hot enough to give off electrons in sufficient number to invalidate the results. The method adopted, therefore, has been to swing the probe by a mechanical means at practically a constant velocity, through the discharge so rapidly that it does not heat up sufficiently to cause trouble. The potential was maintained on the probe by means of a low resistance battery and the current measured by the throw of a ballastic galvanometer properly shunted. To use the measurements to indicate the space potential and the average energy of the electrons, it is not necessary to know the area of the arc stream swept over by the probe but in order to compare the positive ion currents collected at various parts of the arc or in arcs with different currents flowing, it is necessary to know the area swept out. Photographic measurements of the light given off by the arc show that the conditions in the arc over any plane perpendicular to the axis of the arc can be considered to be uniform. It is possible to show that if a probe is moved through the arc at a uniform velocity v, the quantity of current Q which flows through the galvanometer circuit is

$$Q = \frac{\pi r^2 i}{v}, \tag{3}$$

where r = radius of the arc where the probe swings through, and i = the current per unit length of the probe, and depends on the condition of the gas within the arc.

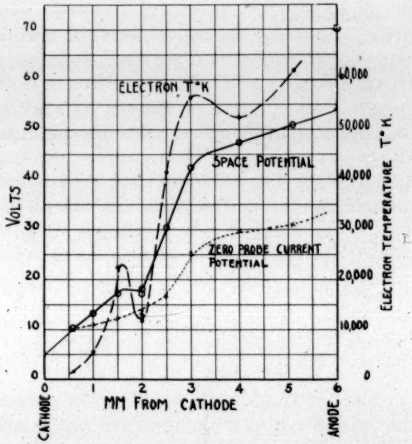
RESULTS OF MEASUREMENTS.

The arc materials studied so far have been (1) cadmium in argon, (2) thallium in argon, and (3) carbon in air.

Cadmium Arc.—The results of the measurements on the cadmium arc in argon at atmospheric pressure showed that the cathode fall was exactly equal to, or very slightly greater than, the ionization potential of cadmium which is 8.9 volts and that the anode fall was of the order of one volt. The field along the arc stream was uniform and about one volt per millimeter. These measurements were made on 4 mm. arcs carrying currents of 1 to 4 amperes. The average energy of the electrons half way between the electrodes increased

slightly as the current was increased. The electron temperatures found were 5400° K. for 1.0 and 2.0 amperes, and 6100° K. for 4.0 amperes. The average electron energies corresponding to these temperatures expressed in equivalent volts are 0.7 and 0.79 volt respectively. A tungsten probe 0.2 mm. diameter was used.

FIG. 3.



Distribution of potential and electronic temperature along the carbon arc.

Thallium Arc.—Measurements of a 2.0 ampere 4 mm. thallium arc in argon showed also that the cathode fall was exactly equal to or slightly higher than the ionization potential of thallium of 6.08 volts. The field along the arc stream in this case was about 1.5 volts per mm. and the average temperature of the electrons 7750° K. which is the equivalent of 1.0 volt. Whether or not this average energy of 1.0 volt is in any way related to the known metastable electron level of 0.96 volt for the thallium atom, is a point we hope to settle by further measurement.

Carbon Arc.—The results obtained on the carbon arc have proved to be by far the most unexpected. The carbons

studied were furnished by Gebrüder Siemens & Co., Berlin, and classified by them as "+ E + HOMOGENKOHLE + E +." Spectroscopically these were found to be the purest of all of the carbons tried out preliminary to the beginning of this study. A very faint trace of sodium was found to be present along the entire length of the arc stream and a trace of iron impurity showed in the spectrum in the immediate neighborhood of the cathode. Since it has been impossible to obtain carbons of greater purity than these, we have not been able to prove that the irregularities in the carbon arc stream disclosed both by the photographs and the probe measurements, are really inherent in the carbon arc or were found in this case as a result of the traces of impurities. A carbon probe burned to 0.4 mm. in dia. was used for the measurements.

The curves on Fig. 3 serve to illustrate the general results so far obtained with the carbon arc. The solid line (heavy over the range of measurement, light in extrapolation) shows the distribution of potential along the arc from the cathode taken as zero to the anode at 70.5 volts, a result in good agreement with the Ayrton [2] value of 69.6 for pure carbons. A straight line extrapolation of the line through the observed points from 0.6 to 1.5 mm. from the cathode gives a cathode fall of about 5.0 volts which is lower than that given by other observers.[3, 4] This value agrees with the estimated value, 4.4 volts, of the ionization potential of the cyanogen molecule given by Mullikan [5] and extends the general observation mentioned above that the cathode fall is equal to or slightly greater than the ionization potential of the gas actively involved. Between 1.5 mm. and 2.0 mm. from the cathode there was no increase in potential while over the range 2.0 mm. to 3.0 mm. the potential increased 25.0 volts. From this point on no irregularities were found. The field of 40 volts per cm. agrees with that found by Hagenbach and Wehrli.

The anode fall of 16.5 volts is lower than that measured by

[2] Ayrton, "The Electric Arc," p. 185.
[3] Ayrton, "The Electric Arc," p. 218. Cathode fall 11.0 volts.
[4] Hagenbach and Wehrli, *ZS. f. Phy.* **26**, 23 (1924). Cathode fall 7.1 volts.
[5] *Phys. Rev.*, **25**, 291 (1924).

Ayrton [6] (34.0 volts) and that calculated by Hagenbach and Wehrli [4] (33.7 volts).

It is interesting to note that the values for the cathode and the anode falls as found by the Langmuir probe exploration coincide almost exactly with the "forward" and the "back" E.M.F. measurements of the cathode and the anode spaces published by Duddell [7] in 1904 and by Hagenbach and Wehrli [4] in 1924. In both cases small intensity high frequency currents, 100 and 190 kilocycles, were used and determinations of an apparent E.M.F. and an IR drop from the probe to the electrode were made. The cathode E.M.F. was found by Duddell to be -5 to -6 volts and Hagenbach found -6.1 volts. The anode E.M.F. was measured as 15 to 17 volts by the former and as 16.7 volts by the latter. The numerical values agree almost perfectly with those now found by the Langmuir probe method to be the true cathode and anode falls.

The measured electron temperatures showed an interesting relationship to the electric fields accelerating the electrons. At the termination of each rise in voltage, namely at 1.5 mm. and 3 mm. there was a maximum temperature of the electrons, and immediately following, over the range of smaller field the electron temperature dropped. This drop was particularly noticeable at 2.0 mm. from the cathode. At the maximum at 1.5 mm. from the cathode, the average energy of the electrons expressed in equivalent volts was about 3.0 volts, thus allowing for many electrons with sufficient energy to ionize the *CN* molecule in a single impact. Over the entire range from 2.5 mm. on, the electrons on the average had acquired sufficient energy to ionize the *CN* molecule easily. Thus it can be said that it is an experimental fact that the electrons have acquired sufficient energy from the field to produce the ionization required for the maintenance of the electric arc in spite of the fact that the fields are small. This observation should make it unnecessary to invoke the indirect explanation based on Saha's equation as given by Compton [8] to explain the ionization known to exist.

[6] Ayrton, "The Electric Arc," p. 215.
[7] *Phil. Tran.*, **203**, 305 (1904).
[8] *Phys. Rev.*, **21**, 286 (1923).

The consistency with which the electron temperature rises while traversing a region of the arc where the field is high suggests that the electrons gain their high temperatures by their acceleration in the field. We shall assume that electrons after collision with molecules come off with a Maxwellian distribution of velocities and that they communicate on the average a fraction α of the energy which they have gained from the field since the last impact. If, under these conditions, X is the field, u the average velocity of the electrons along the axis of the arc, e the electronic charge, and n the number of electrons per c.c., the energy converted into heat per second will be $neuX$. The amount which goes into temperature energy of the electrons, is according to the above hypothesis $(1 - \alpha)neuX$. Thus if T is the temperature of a group of electrons whose motion we follow

$$(1 - \alpha)neuX = \frac{3}{2}kn\frac{dT}{dt} = \frac{3}{2}kn\frac{dT}{dx}u, \tag{4}$$

where k is the molecular gas constant. On integration between two points along the arc we find

$$(T_2 - T_1) = (1 - \alpha)\frac{2e(V_2 - V_1)}{3k}. \tag{5}$$

We can convert an electron energy corresponding to a given temperature T into equivalent volts v by taking

$$v = \frac{3}{2}\frac{k}{e}300T$$

$$= 1.293 \times 10^{-4}T. \tag{6}$$

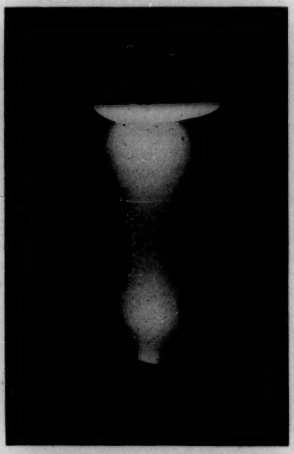
Solving equation (5) we get

$$(1 - \alpha) = \frac{v_2 - v_1}{V_2 - V_1}. \tag{7}$$

The application of this result to the range 2.0 mm. to 3 mm. in Fig. 3 gives $\alpha = 0.78$ while over the range from the cathode fall to 1.5 mm. we get $\alpha = 0.763$. This seems to show that electrons moving along the arc under the influence of the field lose on the average only about three-quarters of the energy gained over their free paths by impact on molecules.

In order to illustrate the error involved in probe measurements, before the Langmuir analysis was proposed, the points showing the probe potentials for which no current flowed to the probe are plotted along the dotted line in Fig. 3. It is easy to see how the irregularities which have been observed above were not detected.

FIG. 4.



Photograph of 4.0 amp., 6 mm. carbon arc.
Light from 4216 Å cyanogen band.

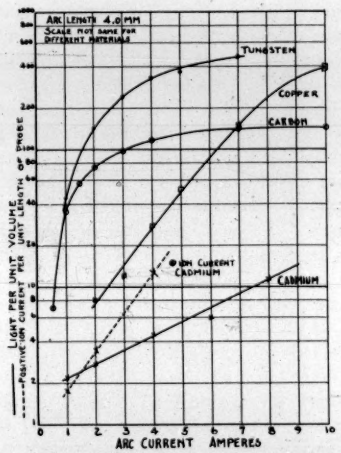
Figure 4 is a reproduction of a photograph taken of an arc 6 mm. long carrying 4 amperes which shows quite clearly the fact that maxima and minima in the light given off the arc stream follow exactly at the points of irregularity as shown by the probe. In particular the maximum of light intensity at 1.5 mm. from the cathode has a direct counterpart in the potential curve of Fig. 3 because at this point there is a marked change in slope in the direction to indicate a region of positive space charge, and therefore, a region of high positive ion concentration.

CORRELATION BETWEEN POSITIVE ION MEASUREMENTS AND LIGHT INTENSITIES.

Probe measurements in the cadmium arc showed that the positive ion current *per unit length* of the probe increased very rapidly with an increase in the current flowing in the arc although the current density over any cross section of the arc has been found to be constant and independent of the current. This observation seems to indicate an apparent increase in the efficiency of the ionization process as the current is increased. Such an increase in efficiency might conceivably be brought about because the volume occupied by the arc stream is directly proportional to the current flowing. The larger volume results in a greater radiation flux and absorption of the resonance radiation in each element of volume and thus increases the efficiency. It is perhaps along these lines that we must look for an explanation of the fact that the voltage drop across the arc decreases as the current flowing increases. Selected radiation, not including resonance radiation, has been found to be emitted without appreciable absorption in passing through the arc. A photoelectric cell has been set up with an appropriate lens system to measure the radiation of a selected wave-length (or range of wave-lengths) which comes from a little cylinder of the arc stream formed by passing two planes perpendicular to the axis of the arc and including 0.5 mm. of the arc stream's length. From previous measurements it is known that the light per unit volume is uniform over such a cylinder and therefore if the total light recorded by the cell is divided by the known area, the light per unit volume will be known and this can be compared with the positive ion current per unit length of the probe. The light intensity measurements showed the same type of rapid increase of intensity per unit volume when the arc current was increased as was found for the positive ion current. Copper, carbon and tungsten arcs also were measured and found to show a great increase in light per unit volume as the current increases. The carbon and the tungsten arcs showed a marked tendency for the light per unit volume to reach a "saturation" value. In view of the fact that the areas of cross section of these arcs are greater than the others measured, a more rapid approach of the emitted

radiation to a saturation value with increasing current is to be expected because of the larger absorption of the light in the arc itself. The curves shown in Fig. 5 serve to illustrate the rapid increase in positive ion current and light per unit volume and also the tendency towards light saturation in the carbon and tungsten arcs.

FIG. 5.



Light intensity and positive ion measurements.

Qualitatively, this increase in radiation has been known by the medical profession for some time and measurements of A.C. arcs between impregnated electrodes summing the radiation along the axis of the arc instead of at right angles to its axis, have been published by Coblentz,[9] Dorcas and Hughes. Their results are qualitatively much the same as the writer's, showing a tendency to saturate at slightly higher currents, although they did not express their results in such a way as to make this point obvious.

It is apparent from the results presented that the use of

[9] Sci Papers of Bureau of Standards No. 539, Nov. 19, 1926.

the Langmuir probe and the correlation of the probe measurements with other physical measurements of the arcs, such as light intensity, ionization potential, etc., opens a whole new field of research, the outcome of which promises to fill in many details of the mechanism of the electric arc which have evaded discovery for a long time.

To Professors W. F. G. Swann and K. T. Compton, I am greatly indebted for many valuable suggestions.

The Liter and the Cubic Decimeter. H. W. BEARCE. (*Science*, May 18, 1928.) In the establishing of the metric system it was intended to derive the units of length, area, volume and mass from the meter which was to be the ten-millionth part of the length of the earth's quadrant from pole to equator. A cube a tenth of a meter on a side was the unit of volume and the mass of this volume of water at its maximum density was the kilogram. Difficulties were encountered in making these plans concrete. It was a task beset by serious obstacles to measure accurately a quadrant of the earth and the meter was later defined by reference to a definite material standard. Furthermore masses could be compared with greater accuracy than was obtainable by deriving a mass from volume measurements, so that the kilogram also was defined by reference to a concrete standard. An additional step was taken by defining the liter as the volume of a kilogram of water at maximum density. The liter as thus defined is 27 parts in a million larger than the cubic decimeter specified by reference to the earth's quadrant, and the milliliter is in the same proportion larger than the cubic centimeter.

The author, who is in the Bureau of Standards, regrets this existing confusion in units and decries the use of 'cubic centimeter' in measuring the volume and density of liquids instead of the correct 'milliliter' (ml.). For the abbreviation of 'cubic centimeter' he prefers 'cm^3' to 'cc.'

G. F. S.

A CONSIDERATION OF TUNGSTEN-FILAMENT LAMPS IN RADIATION THERAPY.

BY

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FOR many years science has been investigating the physiological effects of radiant energy with the result that some definite knowledge is now available. However, almost every question that is asked pertaining to some phase of radiation therapy is wholly unanswerable, or incompletely answerable at best. Seldom does the public "keep up with science" but occasionally it "gets ahead of knowledge." People have knowingly or unknowingly practiced radiation therapy with solar energy since the dawn of savagery. Notwithstanding all this, the entire field is still in the "twilight zone of knowledge." Combining this with the natural desire to grasp at any promising boon to life and to health we have a situation which is fraught with some dangers and many difficulties.

There are uncounted photochemical reactions. Doubtless radiant energy of all wave-lengths in the ultraviolet region plays many parts in chemical processes. It is possible that radiant energy of all these wave-lengths may eventually be used in some manner to benefit the life and the health of human beings. However, we are far from a complete knowledge of these possibilities. Interest in ultraviolet therapy at present is chiefly concentrated in the spectral region between the wave-length limits from 3200 A and 2800 A. Ultraviolet energy of other wave-lengths produces many effects and, therefore, has or will have many practical applications. However, for such purposes as the prevention and cure of rickets, radiations of shorter wave-lengths than 3200 A seem to be the most effective. There are some indications that radiant energy of shorter wave-length than 2800 A, or thereabouts, may be harmful, at least in overdoses. In the absence of complete knowledge it is prudent to avoid the use of radiant

energy in therapy of shorter wave-lengths than 2800 A. This has an attractive philosophical basis, inasmuch as these radiations shorter than λ 2800 do not reach the earth from the sun and, therefore, human beings are not adapted to them or may not have developed the means of using them beneficially. However, this does not mean that they may not be useful, for Roentgen and radium rays have many uses in preserving life and health even though human beings have not been exposed to appreciable amounts in their natural environment.

With the great and increasing interest in ultraviolet radiation, the light-sources in common use are turned to for possible assistance. The sincere and cautious therapist can safely apply any of the special sources of radiant energy, but upon looking toward a possible general use by the public other considerations are important. With tungsten-filament lamps in such prevalent use for lighting purposes the possibilities of their use in ultraviolet therapy receive much attention by the public as well as by physiologists, physicians, and others. The final proof of their efficacy in such a field must await the results of researches, but physical analyses of the radiations throw some light upon the desirability of such researches. There has been a tendency on the part of some to discard this source of radiation without a trial. However, in the present state of scanty knowledge this attitude is unscientific. Obviously, tungsten-filament lamps cannot compete in quantity of ultraviolet energy with solar radiation, with that from the quartz mercury arc, or with other arcs. However, it is legitimate to inquire whether or not the small amount of ultraviolet energy emitted by tungsten filaments, working over long periods of time such as the hours of ordinary illumination in work-places and elsewhere, may not be beneficial. Many persons are exposed to very little sunlight or even skylight for many months in the year. Aside from the relatively feeble skylight which enters our homes, offices and other work-places many of us are exposed no more than a few minutes per day to solar radiation. What is the minimum exposure to ultraviolet energy—both in time and in intensity—that human beings require? These and many other questions remain unanswered.

For many years it has been known that ordinary glass does not efficiently transmit radiant energy shorter than λ 3200. This is true of the ordinary bulbs of tungsten-filament lamps. For this reason it is of interest to learn whether or not it appears worthwhile to equip present filament lamps with special bulbs or to conduct therapeutic researches with them. Measurements of small amounts of ultraviolet energy in definite spectral regions are fraught with many difficulties. In the case of the sun the quantity of ultraviolet energy varies enormously with the sun's altitude, with the composition of the atmosphere, with cloudiness, etc. Incidentally, it is not commonly recognized that light from a clear blue sky is rich in ultraviolet.

Although we have made many measurements of ultraviolet content, both spectrally and with selective filters of rather indefinite cut-offs, the writer prefers to present here the results of computations. This is done with a full knowledge of the limitations of the data, particularly on account of the questions which arise as to the applicability of radiation laws to the ultraviolet. However, inasmuch as we are only interested in this preliminary survey in the order of magnitude of the quantities, the computational method of approach seems satisfactory. In regard to the content of ultraviolet energy between the limits of λ 3200 and λ 2800 in solar radiation at the earth's surface, we shall use a value which in our judgment is satisfactory for the purpose as arrived at from various sources of data and experience. We have chosen the value of two per cent. of the total solar radiation reaching the earth's surface. Perhaps this represents more nearly an average of the maximal content rather than an average. Certainly, throughout many hours of many days and throughout many months, excepting in desert regions of low latitudes, this value is high. However, if this figure is not agreeable to others the data presented herewith may readily be revised. It seems likely that it represents the order of magnitude throughout several hours during the middle of the day on sunny days in summer. The data for the radiation emitted by the quartz mercury arc and solar radiation are based upon measurements. As already stated, the data for the radiation from tungsten filaments are computed and it is assumed that

the bulb is perfectly transparent to the ultraviolet radiations under consideration.

On the basis of equal total energy from various sources of radiant energy the percentages of the total energy throughout the entire spectrum represented by the energy between λ 3200 and λ 2800 are found to be as given in Table I in the column indicated as "Percentages." For ease of comparison relative values are also given in terms of ultraviolet radiation between λ 3200 and λ 2800 taken as unity. The first three sources are filament lamps operating at color-temperatures 2920° K., 3180° K. and 3220° K., respectively.

TABLE I.

	Percentages	Relative
500-watt tungsten lamp designed for 1000-hr. life	0.018	0.009
500-watt tungsten lamp designed for 100-hr. life	0.047	0.024
900-watt tungsten "movie" lamp at 100-hr. life	0.054	0.027
Solar radiation at noon on a clear day	2.000	1.000
450-watt quartz mercury arc	3.150	1.575

Thus it is seen that the ultraviolet energy under consideration is relatively small in amount from tungsten-filament lamps compared with that in equal quantities of solar radiation or of the energy emitted by the quartz mercury arc. In the case of the filament lamps it is of the order of magnitude of one hundredth of that in equal amounts of total energy from the other two sources. However, this is not completely discouraging until the questions already asked—and others—are completely answered by researches.

Now let us compare these on the basis of equal lumens or equal quantities of visible light—that is, on the basis of equal intensities of illumination from the ordinary lighting viewpoint. This is done in Table II. For this transformation the values of lumens per watt as used for the five sources are respectively 19.2, 25.8, 27.3, 100, and 50. By dividing the values in Table I in the column indicated by "Percentages" the watts (radiated between the limits λ 3200 and λ 2800) per lumen are obtained. These values are omitted but for ease in comparison are presented in Table II relative to this energy in solar radiation.

TABLE II.

500-watt tungsten-filament lamp designed for 1000-hr. life	0.05
500-watt tungsten-filament lamp designed for 100-hr. life	0.09
900-watt tungsten "movie" lamp designed for 100-hr. life	0.10
Solar radiation at noon on a clear day	1.00
450-watt quartz mercury arc	3.10

On the basis of ultraviolet energy (of restricted wavelengths) per lumen the case appears more promising for the tungsten-filament lamp until we reflect that solar radiation is so intense that the visible light is measured in thousands of foot-candles reaching a maximum occasionally in the neighborhood of 9000 foot-candles. In artificial lighting with ordinary sources we commonly use only a few foot-candles although the level of illumination is rapidly increasing. However, in the present state of the lighting art an intensity of 20 foot-candles is commonly considered high. Economic and other considerations will eventually push this to much higher intensities, but excepting in special cases such as the motion-picture production-studios, searchlight uses, etc., we do not yet see the age of 1000 foot-candles of artificial light for work-places in sight.

Let us assume for a moment that physiological effects of radiant energy are directly proportional to the product of time of exposure and the quantity of ultraviolet energy. This relationship is not necessarily true over wide ranges. Certainly it does not hold in some other uses of radiant energy and is by no means a universal law. However, assuming for the moment it is true, the same therapeutic result would be obtained in a given time of exposure to 100,000 foot-candles from an ordinary 500-watt tungsten-filament lamp (with a special bulb) as from 5000 foot-candles of solar radiation at noon on a clear day. Such an intensity of illumination from tungsten-filament lamps is wholly impracticable. With the same assumption as in the foregoing, the same therapeutic result would be obtained in 5000 minutes' (83 hours') exposure to 20 foot-candles from the ordinary tungsten-filament lamp (with a special bulb) as from a one-minute exposure to 5000 foot-candles of noon sunlight. If the 500-watt lamp operated at a temperature which reduced its life to 100 hours the foregoing time of exposure would be reduced to one-half, provided the assumption made is tenable.

However, is the assumption tenable? Our eyes, for example, utilize a small quantity of light much more efficiently per unit of light than they utilize a great quantity per unit of light. It is possible that our skin or its receptors of radiant energy may do likewise. To receive the benefits of ultraviolet radiation while working at regular tasks requires that the face and hands in general are sufficient as receiving-stations. In the light of present knowledge this seems quite likely.

The data are presented for what they may be worth. The facts are to the writer at once discouraging and encouraging. Small amounts of ultraviolet energy known to be beneficial are emitted by tungsten filaments. These may be appreciably augmented by increasing the filament temperature. Will researches show that these small quantities operating for long periods, such as all of us spend under artificial lighting markedly benefit us? Researches in this direction will be tedious and time-consuming. However, the evidence revealed by such computations as presented herewith are not wholly discouraging to the contemplation of researches which will answer the many questions which may arise.

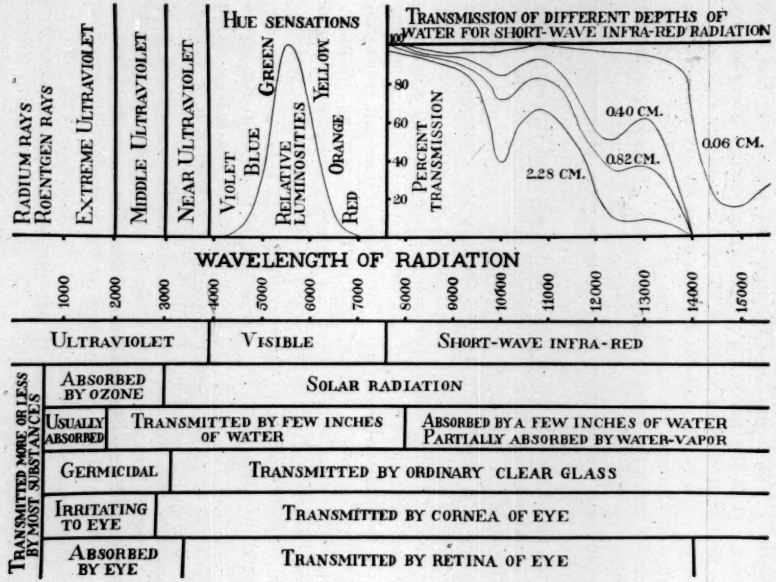
In the foregoing discussion radiation therapy has been discussed within very narrow limits. As knowledge increases there are good reasons for believing that the wave-length limits of beneficial radiation will be greatly extended.[1] If ultraviolet energy of wave-lengths greater than λ 3200 is found to have therapeutic value, the use of tungsten-filament lamps will be more encouraging than the foregoing computations indicate. It is now known that germicidal action [2] extends to considerably longer wave-lengths than λ 3200.

There is a branch of therapy which relies upon heating effect with the attendant reactions such as hyperæmia. Hot towels and heating-pads are commonly known to be efficacious. They heat the body by conduction. Holding an electric filament lamp near the body can produce the same result with greater comfort to the person being treated. All the heating effect, excepting the small amount by conduction

[1] "Light and Health," by M. Luckiesh and A. J. Pacini, Williams and Wilkins Co., 1926.

[2] "Ultraviolet Radiation," by M. Luckiesh, D. Van Nostrand Co., 1922.

FIG. 1.



A diagrammatic presentation of certain data pertaining to radiant energy. (This diagram is taken from Light and Work by M. Luckiesh, D. Van Nostrand Co., 1924.) The wave-length scale is in angstrom units.

from the heated air, is achieved by the absorption of radiant energy. All kinds of lamps and bulbs have been devised and used for this purpose but in the light of present knowledge an ordinary tungsten-filament lamp seems to be best for this purpose. The body consists largely of water. It has been shown [3] that the percentage of incident energy absorbed by the first inch of clear water is 88 per cent. in the case of the treated carbon-filament and is less than 80 per cent. for the tungsten-filament vacuum lamp. For the gas-filled tungsten-filament lamp the percentage is still less. Thus it is seen that radiant energy from tungsten-filament lamps penetrates more deeply into water than that from carbon filaments. The color of flesh is red owing to the blood. From a consideration of the chart [4] presented in Fig. 1 and of spectral characteristics of blood and of these illuminants approximately the same conclusions are arrived at for the blood. Furthermore, where heating at a depth is desired in therapy the knowledge which we possess at the present time does not lead us to a preference for colored lamps unless perhaps red light is used where the greatest heating at a depth is desired with a minimum heating of the flesh near the surface. However, it does not seem that such a procedure is efficient and perhaps is seldom desirable. Using the total energy from an ordinary tungsten-filament lamp the heating at a depth would be the result of the penetration of some energy to the maximum depth, before it is converted into heat, and the conduction of heat from the layers of flesh near the surface to those deeper in the body. With such facts of physics understood the therapist will be guided not only in his researches but in his practice.

[3] "Radiant Energy and the Eye," by M. Luckiesh, *American Journal of Physiological Optics*, 2, Jan. 1921, p. 3.

[4] "Light and Work," by M. Luckiesh, D. Van Nostrand Co., 1924.

THE FERMI-DIRAC HYPOTHESIS OF GAS DEGENERATION AND ITS APPLICATIONS.

BY

E. S. BIELER, Ph.D.

1. INTRODUCTION.

ABOUT three years ago, the German mathematical physicist Pauli [1] gave a very remarkable explanation of the distribution of the electrons in an atom among the possible energy levels in terms of a principle which has been termed the Pauli exclusion principle.

"In any given atom there cannot be two electrons possessing the same combination of the four quantum numbers."

This afforded a logical if somewhat formal reason for the distribution first proposed by Stoner,[2] and amply supported by him on experimental grounds, of the electrons in an atom among the possible levels. In particular, it gave a very striking explanation of the occurrence of 2, 8, 8, 18, 18 and 32 elements in the five successive complete periods of the Periodic Table. Some of the consequences of the application of this principle, especially to the explanation of diamagnetism have already been reviewed in this JOURNAL.[3]

Shortly after this, Fermi [4] in Italy conceived the idea that Pauli's principle might be extended to apply to the molecules in a mass of gas, and thus afford a basis for the explanation of a number of properties of gases at low temperatures. Almost at the same time, Dirac [5] reached the same conclusion on the basis of a similarity between the expression of the properties of molecules and of electrons in Matrix Mechanics.

The list of important phenomena which have already received an explanation on the basis of this extension of Pauli's principle seems already imposing enough to warrant

[1] Pauli, *Zs. f. Phys.*, 31, 765 (1925).
[2] Stoner, *Phil. Mag.*, 48, 719 (1924).
[3] Bieler, *Jour. Franklin Inst.*, 203, 211 (1927).
[4] Fermi, *Zs. f. Phys.*, 36, 902 (1926).
[5] Dirac, *Proc. Roy. Soc. A.*, 112, 661 (1926).

a very serious consideration of the theory on the part of the physicist.

By far the larger number of applications has been to various points of the electron theory of metals, namely,

(*a*) The absence of a contribution of the free electrons to the specific heat of metals.[12]

(*b*) The approximate constancy of the paramagnetic susceptibility of the alkali metals.[7]

(*c*) The constancy of the ratio of thermal to electrical conductivity (Wiedemann-Franz Law).[12]

(*d*) The Volta effect.[12]

(*e*) Thermo-electric phenomena in metals.[12', 17]

(*f*) The emission of electrons from hot bodies.[12, 16]

(*g*) The existence of a sharp threshold frequency in photo-electric emission from metal surfaces.[14]

(*h*) The thermomagnetic and galvanomagnetic effects.[17]

Few applications of the Fermi-Dirac statistics have been made up to the present time outside the realm of the electron theory of metals. It is only rarely that ordinary matter occurs in the gaseous state under such conditions of high density and low temperature that the ordinary classical statistics do not apply just as well. There is a notable exception, however, in the case of the white dwarfs, those stars of which the companion of Sirius is an example, whose enormous density of the order of 50,000 grammes per cc. remained a mystery until Eddington[6] pointed out that it was a natural consequence of the very high state of ionization which their high temperature would cause. A recent application by R. H. Fowler[5] of the Fermi-Dirac statistics to the energy distribution among the component particles has completely cleared up a very serious difficulty which the first form of Eddington's theory presented.

It is hoped that this review will serve a purpose in bringing the new theory before those who have not had a chance to read the original papers, most of which appeared in German publications.[21] The treatment follows partly the lines of the original treatment by Fermi, but the connection between the Fermi-Dirac principle and the de Broglie wave has been taken from a paper by Pauli.[7]

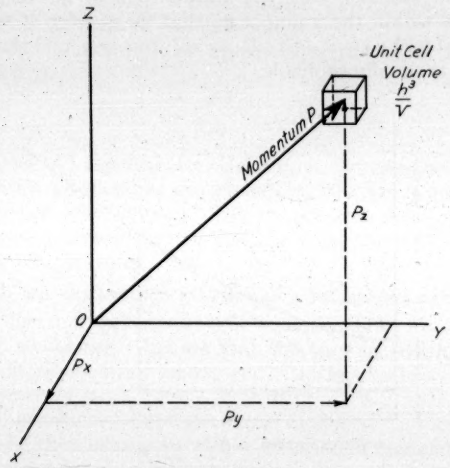
[6] Fowler (R. H.), *Monthly Notices, R.A.S.*, **87**, 114 (1926).

[7] Pauli, *Zs. f. Phys.*, **41**, 81 (1927).

2. GENERAL CONSIDERATIONS.

With the advent of the Quantum Theory and the introduction of definite energy states, there has been a change in the point of view of Statistical Mechanics. Instead of inquiring into the probability that the energy of an individual unit in an aggregate will lie in a given interval, the new statistical mechanics originated by Bose and Einstein [8] inquires into the probability that there will be one or more individuals in the class associated with a given energy state.

FIG. 1.



Division of the momentum space.

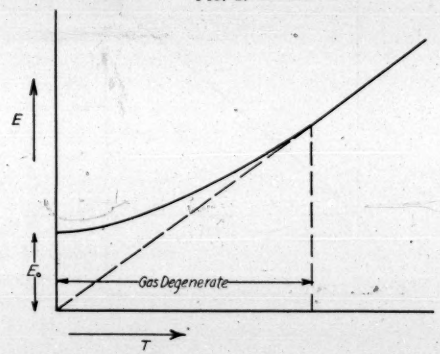
These authors consider a volume V of a monatomic gas and assume that corresponding to each of the molecules in volume V, there is drawn from a common origin a vector whose components are the three components p_x, p_y, p_z of its momentum p (Fig. 1). Each possible energy state then corresponds to a unit cell of volume h^3/V in this momentum space, and the number of molecules in each energy state is repre-

[8] Bose, *Zs. f. Phys.*, **26**, 178 (1924), Einstein, *Berl. Ber.*, 1924, p. 261, 1925, p. 3.

sented by the number of representative vectors that end in each cell. This subdivision of the momentum space into unit cells will seem arbitrary at this stage. It will appear in the next section how it follows from a consideration of the de Broglie wave associated with each molecule.

So far, the statistical methods of Bose-Einstein, and of Fermi-Dirac are in complete agreement.[9] On the one hand, however, Bose and Einstein assume that any number of molecules can be associated with each unit cell of volume h^3/V. Fermi and Dirac, on the other hand, extending the Pauli exclusion principle, which is known to hold for the several electrons within the atom, state that *the number of molecules associated with a given unit cell can only be 1 or 0*, and that either number is equally probable.

FIG. 2.



Relations between temperature and energy in a gas at low temperature.

At the higher temperatures, where the momenta are large, there is practically no restriction placed by the principle on the possible momenta. At low temperatures, the cells near the origin are nearly all filled, and there is a very distinct limitation on the possible momenta. At absolute zero, all the cells nearest the origin are filled, but there is still a very

[9] For a very interesting derivation of the Quantum Statistics of Bose-Einstein and of Fermi-Dirac, as well as Classical Statistics as special cases of a more general statistical treatment, see L. Brillouin, *Comptes Rendus*, 184, 589 (1927).

definite energy, or zero-point energy in the gas. This gas is then said to be *completely degenerate.*

The full line in Fig. 2 shows the relation between energy and temperature in a degenerate gas. The dotted part extending through the origin shows the relation in a non-degenerate gas. E_0 is the zero-point energy.

As we shall see later, the criterion of degeneracy is

$$\frac{n}{(2\pi mkT)^{3/2}},$$

where n = the number of molecules per unit volume, and
m = the mass of one molecule.
Hence, the temperature at which degeneracy first becomes felt varies as,

$$\frac{n^{2/3}}{m}.$$

It is about 5° absolute for Helium, it is therefore 36000° absolute for an electron gas containing the same number of particles per unit volume. Hence, the free electrons in a metal may be considered as forming a degenerate gas at all ordinary temperatures.

3. THE DISTRIBUTION FUNCTION IN A DEGENERATE GAS.

The distribution function will naturally differ from that of classical mechanics. Let us find the way in which energy W will distribute itself among the N molecules in volume V of a degenerate gas.

Pauli considers a cubical volume of side 1. Following de Broglie, he then associates with a molecule of momentum p a frequency ν related to it by the equation,

$$\frac{p}{h} = \frac{\nu}{v}, \tag{1}$$

where v is the velocity of propagation of the waves, and assumes that the number of possible momenta between p and $p + dp$ is equal to the number of possible stationary vibrations of frequencies between ν and $\nu + d\nu$ within the volume.

According to Rayleigh and Jeans, the number of possible frequencies between ν and $\nu + d\nu$ is,

$$Q(\nu, \nu + d\nu) = V \cdot \frac{4\pi\nu^2 d\nu}{v^3}. \tag{2}$$

Hence, the number of possible momenta between p and $p + dp$ is,

$$Q(p, p + dp) = V \cdot \frac{4\pi p^2 dp}{h^3}. \tag{3}$$

The quantity on the right-hand side is the number of unit cells of volume h^3/V in the portion of the momentum space comprised between radii p and $p + dp$. Hence, we have deduced from a consideration of the de Broglie waves, the fundamental fact of the Bose-Einstein statistical mechanics, namely that each possible state is associated with a unit cell of volume h^3/V in the momentum space.

Since the kinetic energy E of the molecule is given by,

$$E = \frac{p^2}{2m}, \tag{4}$$

when m is its mass, equation (3) may also be written,

$$Q(E, E + dE) = \frac{V}{h^3} \cdot 2\pi(2m)^{3/2} E^{1/2} dE. \tag{5}$$

This is the number of possible energy states. We must now find the way in which the molecules will be distributed among these states subject to the Fermi-Dirac restriction that there can be no more than one in each.

Let Q_s be the number of energy states between E_s and $E_s + dE_s$, and let N_s be the number of molecules distributed among these Q_s states. We have then,

$$N_s \leq Q_s, \tag{6}$$

$$N = \Sigma N_s, \tag{7}$$

$$W = \Sigma N_s E_s. \tag{8}$$

Also, the number of ways in which the N_s molecules can be distributed among the Q_s states is,

$$\binom{Q_s}{N_s} = \frac{Q_s!}{N_s!(Q_s - N_s)!}. \tag{9}$$

Hence, the number of ways in which the N molecules can be distributed among all the states is

$$P = \Pi\binom{Q_s}{N_s}. \tag{10}$$

Or, using Stirling's theorem,

$$\begin{aligned} \log P &= \Sigma \log\binom{Q_s}{N_s} \\ &= -\Sigma\left(N_s \log\frac{N_s}{Q_s - N_s} + Q_s \log\frac{Q_s - N_s}{Q_s}\right). \end{aligned} \tag{11}$$

In the actual distribution N and W must be stationary and P a maximum. Now, from (11), we obtain,

$$\delta(\log P) = \Sigma \log\frac{Q_s - N_s}{N_s}\delta N_s. \tag{12}$$

Also, from (6) and (7),

$$\Sigma\delta N_s = 0, \tag{13}$$

$$\Sigma E_s \delta N_s = 0. \tag{14}$$

Hence, using undeterminate multipliers,

$$\Sigma\left\{\log\frac{Q_s - N_s}{N_s} - \alpha - \beta E_s\right\}\delta N_s = 0, \tag{15}$$

where α, β are arbitrary coefficients.

If this is to be true whatever the values of δN_s, then, we must have,

$$\log\frac{Q_s - N_s}{N_s} - \alpha - \beta E_s = 0 \tag{16}$$

or

$$\frac{N_s}{Q_s - N_s} = e^{-(\alpha+\beta E_s)} \tag{17}$$

Hence,

$$N_s = \frac{Q_s}{e^{\alpha+\beta E_s} + 1}, \tag{18}$$

where α and β satisfy the conditions,

$$N = \sum_0^\infty \frac{Q_s}{e^{\alpha+\beta E_s}+1}, \tag{19}$$

$$W = \sum_0^\infty \frac{Q_s E_s}{e^{\alpha+\beta E_s}+1}. \tag{20}$$

Hence, combining (5) and (18) we get,

$$N_s = N(E, E+dE) = \frac{V}{h^3}\cdot 2\pi(2m)^{3/2}E^{1/2}\frac{1}{e^{\alpha+\beta E}+1}dE. \tag{21}$$

At low densities, and for large values of E, this should agree with the Maxwell distribution,

$$N^*(E, E+dE) = KE^{1/2}\cdot\frac{1}{e^{\frac{E}{kT}}}dE. \tag{22}$$

This will be so if

$$\beta = \frac{1}{kT}. \tag{23}$$

We must now evaluate α.
From (19) and (20), we obtain,

$$N = \frac{V}{h^3}\cdot 2\pi(2m)^{3/2}\int_0^\infty \frac{E^{1/2}dE}{e^{\alpha+(E/kT)}+1}, \tag{24}$$

$$E = \frac{V}{h^3}\cdot 2\pi(2m)^{3/2}\int_0^\infty \frac{E^{3/2}dE}{e^{\alpha+(E/kT)}+1}. \tag{25}$$

If we write $\frac{E}{kT} = x$ and put

$$F(\alpha) = \frac{2}{\sqrt{\pi}}\int_0^\infty \frac{x^{1/2}dx}{e^{\alpha+x}+1}, \tag{26}$$

$$G(\alpha) = \frac{4}{3\sqrt{\pi}}\int_0^\infty \frac{x^{3/2}dx}{e^{\alpha+x}+1}, \tag{27}$$

we obtain, instead of (24) and (25),

$$N = V\cdot\frac{(2\pi mkT)^{3/2}}{h^3}F(\alpha), \tag{28}$$

$$E = \frac{3}{2} V \frac{(2\pi mkT)^{3/2}}{h^3} G(\alpha) = \frac{3}{2} NkT \frac{G(\alpha)}{F(\alpha)}. \qquad (29)$$

For very large values of α, corresponding to densities and temperatures where the gas is not degenerate, we can easily obtain $F(\alpha)$ and $G(\alpha)$ in the form of a series, namely,

$$F(\alpha) = e^{-\alpha} - \frac{e^{-2\alpha}}{2^{3/2}} + \frac{e^{-3\alpha}}{3^{3/2}} - \cdots, \qquad (30)$$

$$G(\alpha) = e^{-\alpha} - \frac{e^{-2\alpha}}{2^{5/2}} + \frac{e^{-3\alpha}}{3^{5/2}} - \cdots. \qquad (31)$$

To a first approximation, $F(\alpha) = G(\alpha) = e^{-\alpha}$, so that (28) and (29) reduce to

$$\alpha = \log \left\{ \frac{V}{N} \frac{(2\pi mkT)^{3/2}}{h^3} \right\} \qquad (32)$$

and,

$$E = \frac{3}{2} NkT, \qquad (33)$$

as in the Classical theory.

When α assumes large negative values, on the other hand, corresponding to strong degeneration, $F(\alpha)$ and $G(\alpha)$ assume the assymptotic forms,

$$F(\alpha) = \frac{4}{3\sqrt{\pi}} (-\alpha)^{3/2} \left[1 + \frac{\pi^2}{8\alpha^2} + \cdots \right], \qquad (34)$$

$$G(\alpha) = \frac{8}{15\sqrt{\pi}} (-\alpha)^{5/2} \left[1 + \frac{5\pi^2}{8\alpha^2} + \cdots \right]. \qquad (35)$$

Hence, substituting for $F(\alpha)$ in (28), we obtain,

$$\alpha = -\frac{1}{8} \left(\frac{6}{\pi} \frac{N}{V} \right)^{2/3} \frac{h^2}{mkT} \left\{ 1 - \frac{16\pi^2}{3} \left(\frac{\pi}{6} \cdot \frac{V}{N} \right)^{4/3} \frac{m^2k^2T^2}{h^4} + \cdots \right\}, \qquad (36)$$

which gives for the zero-point energy,

$$\frac{E_0}{N} = \frac{3}{40} \left(\frac{6}{\pi} \right)^{2/3} \frac{h^2}{m} \left(\frac{N}{V} \right)^{2/3}. \qquad (37)$$

Further, if we differentiate E, given by equation (29) with respect to T, we obtain the specific heat at constant volume per gramme-molecule, namely,

$$c_v = \frac{L}{N}\frac{dE}{dT} = \left(\frac{4\pi}{3}\right)^{2/3} \frac{\pi^2 L m k^2 T}{h^2 n^{2/3}}, \qquad (38)$$

where L is the number of molecules per gramme-molecule and n the number per unit volume.

4. APPLICATIONS TO THE ELECTRON THEORY OF METALS.

(*a*) *Zero-Point Energy and Specific Heats.*

A large number of phenomena connected with the flow of electricity in metals, namely electrical and thermal conductivity, thermoelectric, and photoelectric effects have long been explained in terms of the presence in metals of a number of free electrons, of the order of one per atom. On the classical ideas of equipartition these electrons ought to share in the heat motion of the atoms, and therefore to reveal their presence in specific heat measurements. This, they have always failed to do; it is a well-known fact that metals obey the law of Dulong and Petit, and that the whole of the specific heat is accounted for as atomic heat.

The application by Sommerfeld [12] of the Fermi-Dirac statistics to the electron gas formed by these free electrons within the metal seems at last to have cleared up the difficulty, and at the same time to have given a very much more satisfactory explanation of a number of other electrical phenomena in metals.

We have seen that an electron gas ought to show signs of becoming degenerate at temperatures of the order of 36000° C. At ordinary temperatures, degeneration will be practically complete, and the average energy of the electrons will be very near the zero-point energy.

In calculating this, however, we must bear in mind one point. The statistics developed up to now have referred to molecules which possess no energy beyond their energy of translation. The spinning electron of present-day theory [9] has energy of rotation as well. In a magnetic field, it will set itself with its axis of spin in the direction of the field, but its

[9] Goudsmith and Uhlenbeck, *Nature*, 117, 264 (1926).

rotation may be in either direction about that axis. Since the angular momentum is perfectly definite in either case, the electron may exist in two and only two states. It has statistical weight 2. The natural extension of the Fermi-Dirac statistics to the case of the electron is to allow two electrons, one in each direction of spin, in each cell of the momentum space. This leads us to replace n by $n/2$ in the formula for the zero-point energy and for the specific heat.

On substituting numerical values in equation (37), we get for the zero-point energy of the electrons in the case of sodium,

$$\frac{E_0}{N} = 3.14 \times 10^{-12} \text{ ergs.}$$

This is the energy which an electron would possess at 15000° C. on the old equipartition theory. The corresponding voltage is 2 volts.

As for the specific heat, we find, on substituting numerical values in (38) that the contribution of the electrons at ordinary temperatures is of the order of one hundredth of that of the atoms. Hence, we should not expect to detect it in specific heat measurements at ordinary temperatures.

Having regard to the high energy of the electrons at ordinary temperatures, and to their very low specific heats, we see at once why it is that no variation with temperature of the photoelectric threshold has been detected. This experimental fact was also hard to reconcile with the classical electron theory of the metals.

(*b*) *The Susceptibility of the Alkali Metals.*

One of the first successes of the statistical method of Fermi and Dirac was its application by Pauli [7] to the susceptibility of the alkali metals in the solid state. This is known to be paramagnetic and practically independent of temperature. It may be expected to consist of: (*a*) a diamagnetic contribution of the rare-gas like cores, (*b*) the contribution of the valency electrons, which may be diamagnetic or paramagnetic.

The susceptibility of an electron gas composed of rotating electrons which are magnetic doublets might be expected to follow the Curie law,

$$k \alpha \frac{1}{T}$$

and to become enormous at low temperatures.

If the electron gas becomes degenerate at such temperatures, however, this will not be the case. Two electrons of equal and opposite magnetic moment in one cell of the momentum space will give no contribution to the susceptibility. At low temperatures the states corresponding to low momenta will tend to become fully occupied. Hence the susceptibility will remain small.

The formula for the susceptibility is easily obtained from the consideration of the change in the distribution function due to the mutual energy of the magnetic field and the electron. Pauli [7] finally obtains for the susceptibility in the case of complete degeneration,

$$x_0 = 4(\pi/6)^{2/3} G^{2/3} \frac{\mu^2 n^{1/3} m_0}{h^2},$$

where G is the statistical weight of the state, always 2 for the electron,

$$\mu = \sqrt{3}\, \mu_0,$$
$$\mu_0 = 0.921 \times 10^{-20} \text{ e.m.u.}$$

and n = the number of electrons per unit volume, equal in this case to the number of atoms.

Putting in numerical values, we obtain the calculated values in the table below.

TABLE I.

Susceptibility of the Alkali Metals.

Metal	Na.	K.	Rb.	Cs.
Calculated Pauli,[7]	0.66×10^{-6}	0.52×10^{-6}	0.49×10^{-6}	0.45×10^{-6}
Observed McLennan, Ruedy and Cohen [10]	0.61	0.42	0.31	0.42
Lane [11]	0.65	0.54		

The agreement between theory and experiment is still far from perfect, but no other theory gave even an approach to

[10] McLennan, Ruedy & Cohen, *Proc. Roy. Soc. A.*, 118, p. 468.

[11] Lane, *Proc. Roy. Soc. Can.*, 1928.

the experimental results. It should be remembered, however, that no correction has been applied to Pauli's results for the diamagnetic contribution of the atom cores. This would notably lower the theoretical estimate and actually lead us to expect K, Rb and Cs to be diamagnetic.

(*c*) *The Wiedemann-Franz Law.*

The application of the Fermi-Dirac statistics to the problem of electrical and thermal conductivities also shows a marked improvement over the earlier theories. The calculations of Sommerfeld [12] follow exactly the classical treatment of Lorentz,[13] the law of distribution of Fermi being substituted for that of Maxwell. At high temperatures and low densities the formulæ obtained agree exactly with those of Lorentz. At low temperatures and high densities, however, where degeneration is almost complete, the formulæ obtained differ markedly from the classical ones. They are

Electrical conductivity:

$$\sigma = \frac{8\pi}{3}\frac{e^2 l}{h}\left(\frac{3n}{8\pi}\right)^{2/3}. \tag{39}$$

Thermal conductivity:

$$K = \frac{8\pi^3}{9}\frac{lk^2T}{h}\left(\frac{3n}{8\pi}\right)^{2/3}, \tag{40}$$

where l is the mean free path and k the gas constant per molecule. These formulæ are not satisfactory for comparison with experiment, since the mean free path, which occurs in both, is a quantity about which we know very little.

The ratio (K/σ), however, is independent of the free path and admits of direct comparison with experiment. The theory gives,

$$\frac{K}{\sigma} = \frac{\pi^2}{3}\left(\frac{k}{e}\right)^2 T. \tag{41}$$

It is well known that the theories of Drude and Lorentz give expressions of the same form, with numerical factors 3 and 2 however.

[12] Sommerfeld, *Naturwissenschaften*, **15**, 825 (1927); *Zs. f. Phys.*, **47**, 1 (1928).
[13] Lorentz, "Theory of Electrons" (Teubner). Note 29.

The numerical results at 18° C. are as follows:

	Drude.	Lorentz.	Sommerfeld.	Experiment.
$\frac{K}{\sigma} \times 10^{-10}$	6.3	4.2	7.1	7.11

The experimental result quoted is one given by Sommerfeld for the average of the values for the 12 metals, Al, Cu, Ag, Au, Ni, Zn, Cd, Pb, Sn, Pt, Pd, Fe. The closeness of agreement may be slightly fortuitous, for the values for some of the metals chosen differ as much as 10 per cent. from the average, but there is no doubt that the new theory fits the numerical results much better than that of Lorentz.

(*d*) *The Voltaic Difference of Potential, Photoelectricity, and Thermionic Emission.*

The application of the Fermi-Dirac statistics to the explanation of the Voltaic difference of potential, of photoelectricity and of thermionic emission has brought about a similar improvement over the earlier theories. These phenomena are all concerned with the work required to remove an electron from the interior of the metal into the space outside. They will therefore be considered together.

A certain amount of work W_0 is required to remove a free electron at rest from the interior of a metal. If this electron already possesses kinetic energy T, the work is reduced to,

$$W = W_0 - T. \tag{42}$$

Now, in a degenerate gas, the momenta actually possessed by the molecules will be the lowest compatible with the application of Fermi's extension of the Pauli exclusion principle. The total number of molecules with energies not exceeding E_{max} can therefore be obtained by integrating equation (5).

We get

$$n = \frac{1}{V}\int Q(E)dE = \frac{4\pi}{3}\left(\frac{mE_{max}}{h^2}\right)^{3/2}. \tag{43}$$

Hence,

$$E_{max} = \frac{h^2}{2m}\left(\frac{3n}{4\pi}\right)^{2/3}. \tag{44}$$

If the molecule can possess energy in addition to translational energy, equation (44) must be altered by inserting the appropriate value of the statistical weight G, 2 in the case of the electron. Hence,

$$E_{max} = \frac{h^2}{2m}\left(\frac{3n}{8\pi}\right)^{2/3}. \quad (45)$$

As Fowler [14] has pointed out, E_{max} is not an absolute maximum. It is simply a value which is only exceeded by a very small proportion of the electrons. Putting $T = E_{max}$, we obtain, for the electrons which are most easily removed,

$$W = W_0 - \frac{h^2}{2m}\left(\frac{3n}{8\pi}\right)^{2/3}. \quad (46)$$

If, as in Frenkel's [15] earlier theory of electronic conduction, we apply the Virial Theorem, and say that the potential energy is twice the kinetic, and opposite in sign, we get,

$$W = 2T - T = T = \frac{h^2}{2m}\left(\frac{3n}{8\pi}\right)^{2/3}. \quad (47)$$

The voltaic difference of potential between two metals, 1 and 2, is therefore,

$$V_1 - V_2 = \frac{W_2}{e} - \frac{W_1}{e} = \frac{h^2}{2m}\left(\frac{3}{8\pi}\right)^{2/3}(n_2^{2/3} - n_1^{2/3}). \quad (48)$$

This is the same as Sommerfeld's formula, except for the inclusion of the statistical weight 2 of the electron. The difference of potential between Na and Ag accordingly comes out at 3.6 volts instead of 5.7 given by his calculation. The electrochemical series of elements comes out in the proper order for all those metals for which we are entitled to assume that the number of conducting electrons per atom is one.

As Fowler [14] has pointed out, the fact that the electron gas in a metal is almost completely degenerate at ordinary temperatures provides a ready explanation for the existence of a sharp photoelectric frequency.

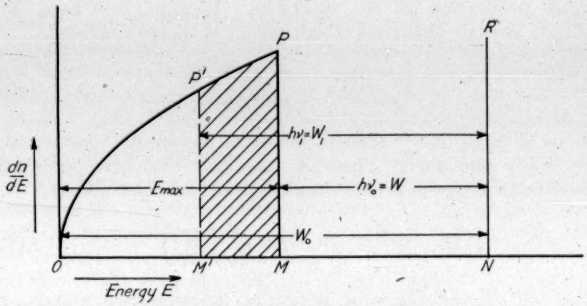
[14] Fowler (R. H.), *Proc. Roy. Soc. A.*, **118**, 229 (1928).
[15] Frenkel, *Zs. f. Phys.*, **29**, 214 (1924).

The electrons which are most easily removed will just be ejected from the metal by frequency ν_0, where,

$$h\nu_0 = W = W_0 - \frac{h^2}{2m}\left(\frac{3n}{8\pi}\right)^{2/3}. \tag{49}$$

The variation of emission with frequency is best illustrated by means of a slight modification of a figure given by Fowler (Fig. 3).

FIG. 3.



Energy relations in the photoelectric effect.

The distribution curve on an energy base is the parabolic arc OP, followed by the sharp drop PM, corresponding to kinetic energy $E_{max} \cdot ON = W_0$ is the kinetic energy which an electron must have in order to be just able to escape through the surface. As the frequency ν of the incident radiation is gradually increased, no electrons will be emitted until ν reaches the value ν_0, when the electrons with maximum kinetic energy can just attain the required critical velocity by absorbing energy $h\nu$. When ν has increased to ν_1, corresponding to energy $W_1 = h\nu_1$, all the electrons represented by area $MPP'M'$ can reach the required critical velocity on absorption of the radiation. Hence the observed sharp photoelectric threshold at frequency ν_0 and the increase in emission as ν is increased above ν_0.

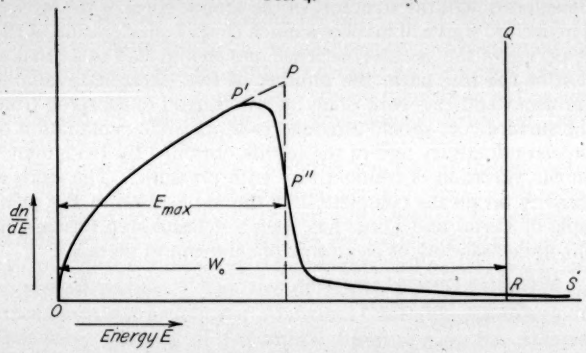
Under actual conditions, PM is not exactly a vertical straight line, but a rapidly falling exponential curve. However, the sharpness of the experimental curve is amply

accounted for. It should be noticed that the theory also accounts for the constancy of the photoelectric threshold as the temperature is varied, since E_{max} does not depend on the temperature.

A closer inspection of the same diagram also accounts for thermoelectric emission. The quantitative treatment is given in papers by Nordheim [16] and Sommerfeld.[12] We shall content ourselves here with a qualitative view of the matter. As equation (21) indicates, the distribution law for large values of E becomes

$$N(E, E + dE) = \frac{V}{h^3} 2\pi(2m)^{3/2} E^{1/2} e^{-(\alpha + E/kT)}\, dE. \qquad (50)$$

FIG. 4.



Energy relations in the thermoelectric effect.

Hence, there is always a certain number of electrons present with large energies, and the number increases with the temperature. The result is that, at high temperatures, the distribution curve of Fig. 3 assumes more the form of that of Fig. 4.

The electrons under the curve to the right of R possess more than the critical velocity for emission, and may escape if they are near the surface, and if they are properly directed. Taking into account the direction, Nordheim and Sommerfeld

[16] Nordheim, *Zs. f. Phys.*, **46**, 833 (1928).

obtained exactly the formulæ obtained by Dushman as a modification of the well known Richardson formula for the case in which the electron gas is degenerate.

The thermoelectric effects, the thermomagnetic and the galvanomagnetic effects have also been treated with very promising results by Sommerfeld.[17] The experiments of Millikan and Eyring [18] on the pulling out of the electrons from metals by means of electric fields have also been satisfactorily accounted for by W. V. Houston.[19]

5. SOME OUTSTANDING PROBLEMS.

The initial phase in building up a satisfactory electron theory of metals on the basis of the Fermi Principle may be regarded as complete. This has been done practically without consideration of the structure of the atomic cores of the lattice. The second step will involve a much closer consideration of the structure of the metals concerned and should lead to a calculation of the free path, the number of free electrons available per atom and the work done by an electron in escaping from the surface. It should also lead to a plausible explanation of superconductivity and of the results obtained by Bridgman [20] on the variation of conductivity with pressure. The work is thus by no means complete, but the application of the principle of Fermi and Dirac has been a definite step forward in our understanding of electronic phenomena in metals.

MACDONALD PHYSICS LABORATORY,
McGILL UNIVERSITY,
MONTREAL,
April 19, 1928.

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[17] Sommerfeld, *Zs. f. Phys.*, **47**, 43 (1928).

[18] Millikan and Eyring, *Phys. Rev.*, **27**, 51 (1926).

[19] Houston, *Zs. f. Phys.*, **47**, 33 (1928).

[20] Bridgman, **27**, 68 (1926).

[21] An excellent short article by H. F. Biggs, summarizing recent progress in these lines has since appeared in *Nature*, **121**, 503 (1928).

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

TWENTY-FIRST NATIONAL CONFERENCE ON WEIGHTS AND MEASURES.

THE Twenty-First National Conference on Weights and Measures was held at the Bureau of Standards on May 22 to 25, inclusive. The following outstanding accomplishments resulted from this conference: Final regulations for lubricating-oil bottles and a new code of specifications and tolerances for grease-measuring devices were adopted; final action was taken on a series of amendments to the regulations for liquid-measuring devices and, largely for purposes of clarification, a series of amendments to the regulations previously adopted for linear, fabric-measuring, and liquid-capacity measures, vehicle tanks, and scales were adopted. Based upon an investigation conducted by the bureau, the transmission drive for taximeters was endorsed.

In point of attendance and the number of States represented the conference surpassed all previous ones. Delegates were present from 28 States and the District of Columbia, and the registration of delegates and official guests reached 246, of which number, 127 were weights and measures officials or representatives. The list of States having delegates in attendance was as follows: Alabama, California, Connecticut, Delaware, District of Columbia, Florida, Georgia, Illinois, Indiana, Kentucky, Maine, Maryland, Massachusetts, Michigan, Missouri, New Hampshire, New Jersey, New York, North Carolina, Ohio, Oregon, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Virginia, West Virginia, and Wisconsin.

The opening address of the President of the Conference, Dr. George K. Burgess, was of particular interest. It was devoted largely to a refutation of the misleading and incorrect statements which have been so generally circulated recently among weights and measures officials and manufacturers relative to H. R. 7208, the bill introduced into the

* Communicated by the Director.

present Congress at the instance of the Twentieth National Conference on Weights and Measures. "A bill to regulate and control the manufacture, sale, and use of weights and measures and weighing and measuring devices for use or used in trade and commerce, and for other purposes." Dr. Burgess included in his address a résumé of the provisions of this bill, a statement of the facts leading up to its introduction into Congress, answers to a number of questions relating thereto originating with the American Institute of Weights and Measures, and a statement of the attitude of the National Bureau of Standards toward the agitation for and against the compulsory adoption of the metric system of weights and measures for the United States a subject which some persons have confused with the object of the above bill. In this connection he said: "As to the attitude of the Bureau of Standards in relation to the compulsory adoption of the metric system, we may state that the facts in the case are that in relation to all proposals advocating the compulsory adoption of the metric system of weights and measures in the United States the policy of the Bureau of Standards is one of neutrality—neither to advocate nor to discourage. The whole subject of compulsory adoption is a highly controversial one and diametrically opposite views are being freely voiced. Most of these are matters of opinion and definite facts are difficult to obtain. So many factors enter into the equation of compulsory adoption that the bureau is disinclined to make the attempt to evaluate it and thus throw the weight of its decision upon the one side or the other. Therefore, I can say definitely and emphatically that the bureau is not advocating the adoption of the metric system for commercial or industrial uses whether by legislation or otherwise, nor has it ever done so during the period that I have been director of the bureau."

Aside from numerous technical subjects considered, the conference program featured several addresses by representatives of business and industry. O. C. Adams, president of the Southern Division of the Great Atlantic and Pacific Tea Company, spoke upon the weights and measures aspects of chain-store operation, and described the steps taken by his organization to meet, and in some instances to anticipate, weights and measures regulations. The general manager of

the National Better Business Bureau, Edward L. Greene, told the conference of many specific instances in which there had been splendid coöperation between weights and measures officials and local better business bureaus. The reweighing of loads of coal, check-ups on gasoline purchases, the reweighing of packages of commodities put up by local dealers, and certain investigations of advertised claims were among the examples cited as typical of a general program on the part of the better business organizations to support and assist in the supervisory activities of the weights and measures official. A. Bousfield, chief engineer of the E. and T. Fairbanks Company, gave a very interesting presentation of the subject, "The Development of Industry," which he illustrated with a large number of lantern slides.

One of the important subjects considered at the conference was the testing of gasoline meters. This subject was presented in two parts, first, testing in the field as carried on by weights and measures officials, and second, testing in the factory as carried on by the manufacturers of meters. Papers describing their methods of conducting field tests were presented by William Foster, city sealer of Springfield, Mass., Theo. A. Seraphin, district supervisor of weights and measures of Philadelphia, Pa., Frank Berka, deputy sealer of Los Angeles, Calif., and John A. Stephenson, city sealer of Rochester, N. Y. Speaking for their respective companies, C. P. Griffith of S. F. Bowser and Company, George D. MacVeagh of the National Meter Company, A. D. MacLean of the Pittsburgh Equitable Meter Company, and H. F. Barrett of the Buffalo Meter Company told of the equipment and methods followed in the factory testing of meters designed for dispensing gasoline at filling stations.

A varied and interesting group of papers was presented by weights and measures officials. Joseph J. Rogers, assistant superintendent of weights and measures of New Jersey, described the recently acquired heavy-scale-testing equipment of his State, while the equipment and methods being utilized in Texas in the regulation of gas, electric, and water meters were described by W. T. Hendrichson, meter inspector of the State division of weights and measures. J. H. Meek, director of the division of markets of Virginia, spoke on coöperation

among weights and measures officials to the end that more nearly uniform regulations may be promulgated and enforced by the several States, while a unique and highly successful method of promoting interest in weights and measures supervision in a given community by essay contests in the high schools, was described in a paper prepared by James J. Dawson, inspector of standards of Massachusetts and the originator of the plan. In the absence of Mr. Dawson, this paper was presented to the conference by Mr. Francis Meredith, director of standards for Massachusetts. The efforts of two State weights and measures associations to keep their members in touch with one another between annual meetings of the association, through the medium of publications supported by the associations, was told by the editor of one of these publications, A. W. Corwin, county sealer of Allegany County, New York. H. N. Davis, deputy commissioner of weights and measures for Vermont, told of the serious effects upon weighing equipment of the recent flood conditions in New England and of the immediate calls made upon weights and measures officials to recondition this equipment for emergency use in the distribution of supplies throughout the stricken area.

Of interest in connection with the testing of heavy-capacity scales was the description given by H. W. Hem of the Toledo Scale Company of the testing device recently developed by his company. This device is designed to test a scale up to 20,000 pounds, and is an outgrowth of the earlier devices of similar character but much smaller capacity which this company has also made.

Some features of the installation of the new plate-fulcrum, master railroad track scale of the Bureau of Standards at Clearing Yard, Chicago, were described by H. M. Roeser of the bureau, who had charge of this installation. This scale will be used for the purposes of calibrating railroad-owned track-scale-testing cars, the test cars and weights belonging to the Bureau of Standards, large weights for industrial uses, etc. The master scale is housed in a special building suitably equipped for carrying on the activities of a testing depot, and will be in charge of members of the track scale section of the Bureau of Standards.

I. J. Fairchild of the commercial standards unit of the bureau reviewed the development of this unit, and described some of the various projects at present occupying the attention of its personnel. Commercial standards, it was explained, are standards which the producers want as a guide for fabrication, and define articles which the distributors want to stock and which the consumers want to buy. In the establishment of commercial standards, the Bureau of Standards relies entirely upon coöperation, and in this field makes no suggestions relative to the standards except upon special request for advice; the procedure is a natural outgrowth of the movement toward the elimination of waste in industry through the limitation of unnecessary variety or the restriction of needless diversification of types, sizes, colors, etc.

A proposed publication of the Bureau of Standards was announced in a paper presented by William Parry of the bureau. A digest of weights and measures cases is planned, to present in one volume an index to weights and measures cases decided throughout the United States, with special analyses appended in connection with those involving outstanding or unusual principles. This publication should prove valuable to all weights and measures officials who have occasion from time to time to present cases in court, for they will be enabled to locate readily decisions previously rendered on similar questions in their own or other States.

A report of the investigation of the Bureau of Standards on the transmission drive for taximeters was made by Ralph W. Smith, who stated the conclusion that, as a result of many observations made on taxicabs and a private car equipped with two meters each, one driven from the front wheel and the other from the transmission, the differences in registration were negligible from the weights and measures standpoint. He added that, in view of numerous advantages which the transmission drive appears to possess as compared with the front-wheel drive, it was recommended that the former be accepted by officials as a proper method of installation for taximeters. Later, the conference, by resolution, went on record as being in agreement with these conclusions.

The special committee on legislation, appointed at the last conference, reported the preparation and introduction

into Congress of H. R. 7208, "A bill to regulate and control the manufacture, sale, and use of weights and measures and weighing and measuring devices for use or used in trade or commerce, and for other purposes." This action was taken in conformity with the instructions of the twentieth national conference. In presenting this report, the chairman of the committee, E. J. Maroney, sealer of weights and measures of New Haven, Conn., denounced recent attacks made upon the National Bureau of Standards in connection with the bill in question by those opposing its passage. Later in the meeting, Mr. Maroney presented a petition for the signature of the members of the conference, this petition setting forth the facts in relation to the introduction of the conference bill, and asserting the confidence of the conference in the integrity of the motives of the Bureau of Standards.

The newly elected officers of the National Conference on Weights and Measures are as follows: President, Dr. George K. Burgess, Director of the Bureau of Standards; first vice president, H. L. Flurry, chief of the division of weights and measures for Alabama; second vice president, Francis Meredith, director of standards for Massachusetts; secretary, F. S. Holbrook, co-chief of the division of weights and measures of the Bureau of Standards; and treasurer, George F. Austin, sealer of weights and measures for Detroit, Mich.

At the Twentieth National Conference held last year, it was decided that in the future there should not be more than one member on the executive committee of the conference from any given State. In accordance with this decision, the following executive committee was elected: All of the officers, ex officio; W. F. Cluett, of Illinois; H. N. Davis, of Vermont; Thomas Flaherty, of California; William Foster, of Massachusetts; S. T. Griffith, of Maryland; T. F. Mahoney, of Tennessee; E. J. Maroney, of Connecticut; I. L. Miller, of Indiana; A. B. Smith, of Pennsylvania; W. A. Payne, of New York; V. A. Stovall, of Texas; C. V. Fickett, of Maine; B. W. Ragland, of Virginia; C. W. Roberts, of the District of Columbia; W. F. Steinel, of Wisconsin; H. A. Webster, of New Hampshire; H. S. Jarrett, of West Virginia; J. H. Foley, of New Jersey; and M. A. Bridge, of Ohio.

CONFERENCE OF UTILITY COMMISSION ENGINEERS.

THE sixth annual conference of state utility commission engineers, held at the bureau May 31 and June 1, was attended by 24 engineers from 12 states, the District of Columbia and two provinces of Canada. The widespread interest in these meetings is shown by the fact that California, Oklahoma, Iowa, Wisconsin, Florida, and Alabama were represented, in addition to most of the northeastern states which have commissions actively interested in engineering problems.

The value of these conferences arises not merely from the engineering papers presented and discussed but even more from the personal contacts established, the opportunity to compare experience, and the interchange of information as to the way in which the engineering organizations of the several states operate. Questions of a more or less detailed sort arising from the operations of the commissions constitute a large part of the program. Since these questions are treated from the point of view of the commissions rather than in their more general aspects, the proceedings of the conference are not published.

The bureau acts as host for these conferences, but the programs are arranged by a committee of the engineers and include commission problems outside the scope of the bureau's work. The papers included in this year's program were as follows: "Depreciation in Connection with Appraisals," by H. Carl Wolf, chief engineer, Maryland Public Service Commission; "Effect of Reduced Cost of Steam Generation on Development and Potential Value of Water Powers," by C. M. Larson, chief engineer, Railroad Commission of Wisconsin; "A Fuel-price Clause in Rates for Domestic and Commercial Gas Service," by A. G. Mott, chief engineer, California Railroad Commission; "Inducement Form of Rate for Residential Use of Gas and Electricity," by C. R. Vanneman, chief engineer New York Public Service Commission; "Development of Rural Electric Service in California," by A. V. Guillou, assistant chief engineer, California Railroad Commission; "Gas Service Problems in Connection with the Revision of Bureau of Standards Circular 32," by E. R. Weaver, chemist, Bureau of Standards; "Accidents and Approved Protective Devices at Grade Crossings of Railroads and Highways," by E. Irvine

Rudd, chief engineer, Connecticut Public Utilities Commission; "Discussion of Fourth Edition of National Electrical Safety Code," by M. G. Lloyd, electrical engineer, Bureau of Standards.

The committee elected to take charge of the 1929 conference consists of A. G. Mott, chief engineer, Railroad Commission of California, chairman; Col. Philander Betts, chief engineer, New Jersey Board of Public Utility Commissioners, vice-chairman; I. F. McDonnell, chief engineer, Alabama Public Service Commission; and J. Franklin Meyer of the bureau, as secretary.

ELECTROLYSIS SURVEYS BY LOCAL UTILITIES COMPANIES.

WITHIN the last year the Bureau of Standards has had several requests for assistance in determining the condition of underground structures with respect to electrolytic corrosion. The bureau's staff of electrolysis engineers has been reduced to one man, and it is no longer conducting field research in electrolysis. It is possible, however, in some cases to assist local utilities in improving their electrolysis conditions if all of the utilities concerned in a given locality are willing to cooperate. At present the bureau's engineer is directing two electrolysis surveys, one in Buffalo, and the other in Duluth. In each case a local electrolysis committee has been formed and a local engineer selected to collect data with the assistance of men furnished by each of the coöperating utilities.

From time to time the bureau's engineer visits the electrolysis committees and advises them as to what data are needed, the interpretation of their results and the steps to be taken to improve electrolysis conditions. The entire expense of the survey is borne by the local utilities. This method of handling electrolysis problems seems to have some advantages in cases where the local utilities wish to solve their own problems without the assistance of a consulting engineer. Not the least of these advantages is the better understanding by each local engineer of the viewpoints and problems of utility organizations other than his own.

CODE FOR ELECTRICITY METERS

THE third edition of the code for electricity meters has been issued by the sectional committee that has had the revision in charge. The Bureau of Standards, the Association of Edison Illuminating Companies, and the National Electric Light Association have been the sponsors for the project, under American Engineering Standards Committee procedure. The chairman of the sectional committee was a member of the staff of the bureau, and the work of revision has been carried on under his direction. On the sectional committee were representatives of the manufacturers of electricity meters, of public utility companies, public service commissions, municipal electricians, scientific instrument makers, and testing and research laboratories.

The code contains chapters on definitions, standards, metering, installation methods, laboratory and service tests, and specifications for the acceptance of types of watthour and demand meters, and auxiliary apparatus for use with meters. It is published by the National Electric Light Association (420 Lexington Avenue, New York, N. Y.), one of the sponsors, from whom copies are obtainable at $2.00 each.

THE STATUS OF FREQUENCY STANDARDIZATION.

IN a paper which appeared in the May, 1928 *Proceedings of the Institute of Radio Engineers*, p. 579, under this title, J. H. Dellinger, chief of the radio section of the bureau, shows that frequency standardization, of hitherto laboratory character only, has become of first-rank importance in reducing radio interference. The recent International Radio Conference recognized frequency as the cornerstone in the radio structure by devoting its major attention to a frequency allocation to provide for the orderly development of all radio services.

Because of increasing use of all available radio channels, particularly those for broadcasting and the very high frequencies, the requirements of frequency measurements are a hundred times more rigorous than they were five years ago. The perfection of standards and measurements to the necessary accuracy requires the most intensive work by the Government and by various large organizations to produce

standards and instruments that can be used to keep radio stations each operating on its own channel. This development has been facilitated by a special coöperative plan organized by the Bureau of Standards a year ago and involving the Commerce, Navy, and War Departments, the General Electric Company, the Westinghouse Company, American Telephone and Telegraph Company, Radio Corporation, and the General Radio Company.

Piezo oscillators are now available to hold radio station frequencies extremely constant. For instruments of this type equipped with temperature control, national and international comparisons have shown that they are reliable to a few parts in 100,000.

This brings in sight the possibility of the use of special piezo oscillators in broadcasting stations, which will hold the frequency so close that several such stations can operate simultaneously without heterodyne interference on the same frequency. This is the only practical scheme so far developed for solving the problem of too many broadcasting stations.

The use of frequency standards of this high accuracy is also vital to all users of the very high frequencies. Many more high frequency channels will become available when all stations use the best available frequency standards and keep the stations on their frequencies with great accuracy.

MEASUREMENT OF LARGE VOLUMES OF GAS.

THIS is the fourth year in which the Bureau of Standards has actively coöperated with the gas measurement committee of the Natural Gas Department of the American Gas Association on methods for measuring large volumes of gas.

In 1925, the first year of this work, the committee conducted some tests on three orifices against a covered gas holder, made available for the work by the East Ohio Gas Company of Cleveland, Ohio. The object of these tests was to determine the discharge coefficients for these orifices under very definite and limited conditions.

The next year, 1926, the work undertaken was a study of the effects of many types and combinations of pipe fittings at various distances from the orifice, and also the effectiveness of

different designs of straightening vanes in eliminating the disturbances produced by the fittings. As a result of this work, which was conducted at the plant of the Iroquois Gas Corporation, Buffalo, New York, the committee prepared and issued a tentative code on the installation of orifice meters. Copies of this code may be obtained by writing to the American Gas Association, Natural Gas Department, New York, N. Y.

During 1927 the work of 1926 continued, using a slightly modified set-up to check the disturbance measurements. Several important conclusions have been drawn from these experiments, among them the following:

When a swedge is used upstream from the orifice, straightening vanes must not be used between the swedge and orifice if a larger orifice flange is installed.

Disturbances caused by a combination of various fittings have an effect proportional to the distance of the disturbance from the orifice in terms of pipe diameter. In other words, the usual theory of geometrical relationships is found to hold.

Last year an extensive series of tests was started in order to study the effect on the discharge coefficient of changing the rate of flow. This series served as a check on similar tests made by the Bureau of Standards at Edgewood Arsenal, and showed changes of the same kind and approximately the same magnitude as recorded in the previous tests.

During the coming summer the work at Buffalo will be continued in line with a program decided upon some time ago. The preliminary arrangements included the installation of a new 4-inch pipe in a so-called commercial line, with two orifice flanges. Tests will be made with 25, 50 and 75 per cent. diameter ratio orifices at the highest possible pressure, followed by ones at lower pressures.

When making the tests at high line pressures it will be necessary to make some auxiliary tests on the gas itself to determine its super-compressibility, i.e., its deviation from Boyle's law, and also to determine the specific gravity of the gas as referred to air. An instrument for determining the super-compressibility of a gas has been constructed at the Bureau, and trial tests with it on air and carbon dioxide have given results in satisfactory agreement with existing data.

After these tests, and with the 4-inch line still in place, the

rate of flow tests will be checked using 25, 50, and 75 per cent. orifices. The 4-inch will then be replaced by a 12-inch line set-up with vanes and pressure taps at points geometrically similar in location to those used last year for the 8-inch line, and tests made with 25, 50, and 75 per cent. (diameter ratio) orifices at rates of flow as high as can be obtained.

If the results of tests on the 4-and 12-inch lines indicate the need for further work on orifices or pipes of other sizes, such as 2-inch pipe, this work will be undertaken if time permits. In addition, tests on 6 x 8, 6½ x 8, and 7 x 8 inch orifices have been recommended in order to indicate the probable accuracy of measurements in these sizes.

Tests to supplement those on the 4-inch line at high static pressures will probably be carried out at another location, where pressures up to at least 350 lbs./in.² are available. These tests would be started as soon as those on the 4-inch line at Buffalo are completed, and would be carried along with the other runs. This will mean that two crews will be kept at work for a large part of the time. H. S. Bean, chief of the gas measuring instrument section of the bureau, has been assisting the committee in developing its program and since last year has been in charge of the actual testing.

The question of extending these investigations to some mid-continental field, where pressures of 600 lbs./in.² or more are available, is being considered by the committee. This is an important question because there are already in service transmission lines with working pressures of 500 lbs./in.² or higher. Some tests may also be needed on casinghead gas at sub-atmospheric pressures. These tests would be complicated by the presence of condensible vapors and fog. It is from casinghead gas that most of natural-gas gasoline is recovered, a most important by-product of the industry.

APPARATUS FOR OBSERVATION OF THERMAL EXPANSION OF REFRACTORIES FROM 20 TO 1800° C.

THE increasing use at high temperatures of fire-clay refractories and special refractories makes it desirable to add to the present knowledge on the expansion behavior of these materials at elevated temperatures. The bureau has accord-

ingly undertaken a study of the thermal expansion or contraction of a number of refractory materials from 20° to 1800° C., or in the case where softening occurs before reaching 1800° C., to the maximum temperature possible.

The desired temperatures are supplied by a high frequency induction furnace having a hollow cylindrical core of graphite 6 x 12 x ½ in., in which the heat is generated by induced current. The ends of the graphite cylinder are closed as much as possible to prevent oxidation of the graphite which proceeds rapidly at high temperatures. Specimens approximately 6 in. long and 1 in. in cross section are set on end within a muffle. 3 in. in diameter, prepared from zirconium silicate. It was found by experiment that all of the special refractories, except graphite, available for use as part of a set-up within the furnace, proved unsatisfactory because of softening or cracking. Graphite also has a uniform and comparatively low rate of thermal expansion throughout the range of temperature used in this work. Shapes prepared from graphite are used, therefore, as the table on which the specimen stands, as well as for transmitting the linear movement of the specimen to a micrometer dial. A piece of tungsten metal, 1 in. square and .015 in. thick, is placed between each end of the specimen and the graphite pieces to prevent reactions occurring at high temperatures between a specimen and the graphite. The temperature of the zone immediately surrounding the specimen is obtained by means of two thermocouples, inserted through the bottom of the furnace, and placed so that one is near the top and the other near the bottom of the specimen. The thermocouples are removed at approximately 1400° C. and temperatures thereafter up to 1800° C. are obtained by means of an optical pyrometer sighted on the bottom of a graphite tube approximately ¼ in. from one side of the specimen. A micrometer dial fastened by an adjustable holder to a rack, having legs of fused quartz tubing, records the movement of the specimen as well as the movement of the table on which the specimen rests and the system which transmits this movement to the dial. Correction, to take care of the expansion of the system, was determined by observing the movements of materials of known expansion. The difference between the total recorded movement and the known expan-

sion was taken as the correction necessary at any chosen temperature. Fused quartz was used for this work up to 1100° C. and the correction curve extrapolated from 1100° to 1800° C. The latter part of the curve was also checked by expansion observations on a specimen of graphite.

Data with this apparatus have been obtained up to the present on periclase, graphite, and mullite from 20° to 1800° C.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

PLASTICITY AND SOLVATION OF CELLULOSE ESTERS.[1]

By S. E. Sheppard, E. K. Carver, and R. C. Houck.

NUMEROUS theories are reviewed which explain why some substances are better solvents for cellulose esters than others, and especially why mixtures of solvents are so often better than the pure solvents.

Hildebrand's polar—non-polar theory is applied with certain amplifications to cellulose acetate sols in alcohol—chloroform mixtures containing varying amounts of water. The results as shown by the curves are in good agreemene with the theory. The relation of the composition of tht solvent to the viscosity was studied.

THE FALLING SPHERE VISCOMETER AND PLASTICITY MEASUREMENTS.[2]

By H. E. Phipps.

AN investigation was made to determine whether or not the falling sphere viscometer could be used as a plastometer. A series of 1/8 inch spheres of different densities were used and plasticity curves were obtained with cellulose acetate solution. The shearing force applied by the different spheres varied from 10 to 600 dynes per cm^2. These curves did not agree entirely with those obtained with the Bingham and Murray plastometer, because of a difference in the type of flow of the plastic substance in the two instruments. The falling sphere instrument can be used to determine plasticity where present at low rates of shear.

* Communicated by the Director.

[1] Communication No. 316 from the Kodak Research Laboratories and published in *Colloid Symposium Monograph* 5: 243. 1927.

[2] Communication No. 317 from the Kodak Research Laboratories and published in *Colloid Symposium Monograph* 5: 259. 1927.

MOLECULAR ORIENTATION AT SURFACES OF SOLIDS. II. THE WORK OF ADHESION OF THE SATURATED FATTY ACIDS FOR WATER.[3]

By A. H. Nietz.

WHEN work of adhesion of the fatty acids is plotted against number of carbon atoms, the adhesional work shows a marked minimum in the neighborhood of 12 to 14 carbon atoms, beyond which there is a very pronounced increase.

The alternating effect shown by odd and even acids is very marked, the odd acids showing two enantiotropic forms. The β odd and even acids lie on a single smooth curve, the α odd modifications showing alternating higher values.

The alternation and two sets of values for α and β odd acids are attributed to differences in crystal structure.

The general trend of the curve for adhesional work against number of carbon atoms is considered as partly due to the general nature of the adhesional energy-temperature relations and partly to the mechanical effects of the length of the carbon chain.

THE DEPENDENCE OF THE RESOLVING POWER OF A PHOTOGRAPHIC MATERIAL UPON THE CONTRAST IN THE OBJECT[4]

By O. Sandvik

The resolving power of a photographic material may be defined qualitatively as the ability to show fine detail in the picture. It is defined numerically as the number of lines and spaces per millimeter which it resolves. This definition, however, is rather inadequate since resolving power depends on many factors, such as the ratio of the width of the line to the width of the space, the color temperature of the light image, or the wave-length where monochromatic radiation is in question, and the relative contrast in the subject.

The present paper gives some results of an experimental investigation of the dependence of resolving power upon the relative contrast in the test object, where relative contrast is

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[3] Communication No. 323 from the Kodak Research Laboratories and published in *J. Phys. Chem.* **32**: 620. 1928.

[4] Communication No. 334 from the Kodak Research Laboratories and published in *J. Opt. Soc. Amer.* *16*: 244. 1928.

defined as the ratio of the photographic intensities of two adjacent small areas to be resolved.

The method of investigation was to photograph in a reducing camera a series of parallel line test objects differing only in relative contrast, and by microscopic examination of the developed photographic images to determine the maximum resolving power for the respective objects.

The results show that the resolution changes very rapidly with contrast at low contrast values. Thus, with no resolution at unit contrast, the resolving power reaches approximately 65 per cent. of its maximum value for a test object density of 0.5, that is, a transmission through the opaque spaces of 31.5 per cent. or a relative contrast of 3.17; and 87 per cent. of its maximum value when the test object density is 1.0, transmission 10 per cent. and relative contrast is 10. The maximum value of resolving power is reached when the test object has a relative contrast of approximately 100 to 200.

LIGHT FILTERS FOR THE ISOLATION OF NARROW SPECTRAL REGIONS[5]

By L. A. Jones

Data are given relative to a series of light filters by means of which relative narrow bands of radiation may be isolated. These bands are spaced through the region from 300 to 900μ. Dyed gelatin, colored glass, and solutions of stable inorganic salts are used in the construction of these filters.

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[5] Communication No. 335 from the Kodak Research Laboratories and published in *J. Opt. Soc. Amer.* 16: 259. 1928.

The Disappearance of Gases into Glass under the Action of the Electric Discharge. JAMES TAYLOR. (*Nature*, May 5, 1928.) Sodium passes through glass by the action of the electric discharge. In the present experiment the author produced positive ions in several gases at low pressures. By the application of an electric field these ions were brought to the inner surface of a thin-walled bulb of soda glass immersed in molten sodium nitrate after having been well baked out. The electric current traversing the walls of the bulb and the disappearance of the gas were measured concurrently. With hydrogen, oxygen and nitrogen direct proportionality was found between the quantity of gas that disappeared from within the tube and the quantity of electricity that traversed its walls. "For hydrogen, every electron charge passed involves the disappearance of one hydrogen molecule. For oxygen and nitrogen, every two electron charges passed involves the disappearance of one atom of oxygen or nitrogen respectively. For helium a current flowed but no disappearance of gas took place." This result with helium precludes the possibility of attributing the disappearance of the gases to accelerated diffusion, for in that case "helium should pass through about twenty times as quickly as hydrogen."

In view of his finding both glass and quartz to have considerable conductivity of an electrolytic nature at the temperature of the experiment the author assigns the disappearance of the gas to electrolytic decomposition of the glass. In the case of hydrogen water is probably formed that goes well into the thickness of the wall.

G. F. S.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY AND SOILS *

THE SPECTROPHOTOMETRIC EVALUATION OF MIXTURES OF METHYLENE BLUE AND TRIMETHYL THIONIN.[1]

By Walter C. Holmes.

[ABSTRACT.]

SPECTROPHOTOMETRIC analysis affords the most convenient means for distinguishing between methylene blue and trimethyl thionin, and for determining the relative proportions in which the dyes are present in a mixture. The methods depend upon the determination of an "absorption ratio." Suitable ratios for the purpose are those of the extinction coefficients at 640 μ to those at 670 μ in solutions containing 50 per cent. by volume of alcohol or of acetic acid. Ratio values are given for eleven mixtures with each solvent, and a graph is plotted from these data. It was found that ratio values were but little affected by moderate variations in hydrogen ion concentration, dye concentration, or neutral salt concentration.

MONOCHROMATIC LIGHT FILTERS FOR THE VISIBLE SPECTRUM.[2]

By Walter C. Holmes.

[ABSTRACT.]

FORMULÆ are given for nine light filters in the visible spectrum between the range of 450 and 700 μ. The filters are aqueous solutions containing copper sulphate together with various dyes, in such proportions as afford approximately 4 per cent. light transmission in 2 cm. layers.

* Communicated by the Chief of the Bureau.

[1] Published in *Stain Technology*, 3: 45–48, April, 1928.

[2] Published in *American Dyestuff Reporter*, Jan. 23, 1928, pp. 31–32.

FUMIGATION OF STORED-PRODUCT INSECTS WITH CERTAIN ALKYL AND ALKYLENE FORMATES.[3]

By R. T. Cotton and R. C. Roark.

[ABSTRACT.]

THE vapors of methyl, ethyl, n-propyl, isopropyl, n-butyl, sec-butyl, isobutyl, isoamyl, and allyl formates were tested against rice weevils, clothes moths, carpet beetles, and furniture beetles. All were toxic to these insects. None of the formates tested had an adverse effect upon the germination of wheat. All these formates, except the methyl and ethyl formates, can be made free from fire hazard by the addition of carbon tetrachloride to the extent of from 60 to 75 per cent. by volume of the mixture.

FUMIGATION TESTS WITH CERTAIN ALIPHATIC CHLORIDES.[4]

By R. C. Roark.

[ABSTRACT.]

TWENTY-ONE aliphatic chlorides were tested against rice weevils in flasks half filled with wheat, and against larvæ of the clothes moth, black carpet beetle, and furniture beetle in a 500-cubic foot fumigating vault. It was found that several of the chlorides possess toxicity to stored product insects. From the standpoint of availability, cost, effectiveness and freedom from fire hazard ethylene dichloride in a mixture of 3 volumes of ethylene dichloride to 1 of carbon tetrachloride appears to be the most promising as a general fumingant. Although more toxic than ethylene dichloride, tert-butyl chloride requires a larger proportion of carbon tetrachloride to render it free from fire hazard and cannot be used in metal-lined vaults owing to its tendency to break down and attack the metal. Trichloroethylene is non-inflammable and shows considerable toxicity in vault fumigation at temperatures of 80° F. or over. None of the materials injured the germination of wheat.

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[3] Published in *Ind. and Eng. Chem.*, 20: 380–382, April, 1928.

[4] Published in *J. of Economic Entomology*, 21: 135–142, Feb. 1928.

BIOLOGICAL VALUES OF CERTAIN TYPES OF SEA FOOD. II. VITAMINS IN OYSTERS (OSTREA VIRGINICA).[5]

By D. Breese Jones, J. C. Murphy, and E. M. Nelson.

[ABSTRACT.]

FRESH Chesapeake oysters were frozen, ground, and fed to albino rats. The experiment showed that oysters are a good source of vitamins A, B, and D.

Two grams (0.32 gram on a dry basis) of oysters furnished sufficient vitamin A to cure rats of xerophthalmia. Tests made by the curative method showed that 3.5 grams (0.56 gram dry basis) of oysters contained nearly enough vitamin B to supply the needs of young rats. For long-continued normal growth, however, a little more than 5 grams (0.8 gram dry basis) was required. Five grams of oysters given to rachitic rats daily for 10 days induced slight calcification of the long bones, comparable with that produced in the same length of time by 4 mg. of good cod liver oil. The same quantity of oysters induced about half calcification in 15 days and complete calcification of the rachitic metaphyses in 20 days.

Oysters were found deficient in the factor required for reproduction and rearing of young.

Dehydration at 40° C. under reduced pressure (10 to 15 mm.) inactivated vitamins A and B in oysters.

THE PRODUCTION OF GLUCONIC ACID BY THE PENICILLIUM LUTEUM-PURPUROGENUM GROUP. II. SOME OPTIMAL CONDITIONS FOR ACID FORMATION.[6]

By Horace T. Herrick and Orville E. May.

[ABSTRACT.]

EXPERIMENTS were conducted to determine the effects of temperature, concentration of glucose, and inorganic nutrient media on the production of acid by the *Penicillium luteum-purpurogenum* group when cultured on glucose solutions.

It was found that 25 degrees is the temperature most favorable for the formation of acid.

Good percentage yields of acid were obtained from both

[5] Published in *Ind. and Eng. Chem.*, 20: 205–219, Feb. 1928.

[6] Published in *J. of Biological Chem.*, 77: 185–195, April, 1928.

the 20 per cent. and the 25 per cent. glucose solutions. The actual quantity of acid, however, was somewhat larger with the 25 per cent. solution.

In the search for the inorganic salt solution most efficient as a nutrient, the effects of different concentrations of magnesium phosphorus, potassium, and nitrogen were determined. On the basis of the data obtained a standard nutrient salt solution of the following composition was prepared:

	Gm. per L. of glucose solution.
$MgSO_4.7H_2O$	0.25 (0.00245% Mg, 0.00325% S.)
KCl	0.05 (0.0026% K)
Na_2HPO_4	0.1 (0.00086% P)
$NaNO_3$	1.0 (0.016% N)

It was found that when ammonium salts were used as a source of nitrogen the production of acid was greatly inhibited although the growth of the organism was normal.

THE DETERMINATION OF SUGARS IN TANNING MATERIALS.[7]

By I. D. Clarke and R. W. Frey.

[ABSTRACT.]

A CRITICAL study is presented on the sugar content, or Fehling's-reducing-power, of a variety of tannin raw materials and extracts. A modification of the method of the American Leather Chemists Association for the determination of sugar in leather is used. It is shown that the effect of the time of hydrolysis upon the sugar yield depends upon the material being examined. Extensive data are given on the lead, phosphate, and acetate content and the effective acidity, or hydrogen ion concentration, at the several stages in the determination. Some preliminary results are given on the use of baker's yeast in determining fermentable sugars, which results suggest interesting possibilities in such a procedure for determining significant differences in the nature of the sugars in various tanning materials. Proposed methods for the determination of total sugars, reducing sugars, non-fermentable sugars, and fermentable sugars in tanning materials and extracts are outlined in detail.

[7] Published in *J. Amer. Leather Chemists Assoc.*, **23**: 91–108, March, 1928.

STUDIES ON GOSSYPOL.
III. OXIDATION OF GOSSYPOL.[8]

By E. P. Clark.

[ABSTRACT.]

UPON oxidation of gossypol with alkaline permanganate, formic, acetic, and isobutyric acids were identified as reaction products. The quantity of each acid formed was determined. The quantity of isobutyric acid obtained was equal to 92.1 per cent. of the quantity required by theory it if is assumed that 1 mol of gossypol yielded 1 mol of acid. Under the conditions of the experiment the presence of isobutyric acid as a decomposition product of gossypol indicates the probable presence in the gossypol molecule of a side chain consisting of at least the isobutyl group.

[8] Published in *J. of Biol. Chem.*, 77: 81–87, April, 1928.

A Note on Corona at High Humidity. A. W. SIMON. (*Proc. Nat. Acad. Sciences*, March, 1928.) The experiments were made for the Tennessee Coal, Iron and Railroad Co., Birmingham. A series of " parallel copper wires equally spaced and hung parallel to and equidistant from two parallel steel plates with rounded edges " was maintained at negative voltages by connection with a synchronous rectifier. Observations on the corona had been made previous to December 12, 1927. Heavy rain fell thereafter until December 15, and the observations later described were made while the rain was falling. As the apparatus was near an open window the relative humidity was not far from 100 per cent. " Whereas ordinarily, as the voltage was gradually raised, heavy visual corona appeared and persisted up to arc-over, on these two days no corona was visible between the plates, and the current passing from the wires to the plates was enormously reduced. Moreover, on attempting to raise the voltage between the plates, a point was soon reached where a series of intermittent sparks passed across between the electrodes." These sparks appeared at several places simultaneously and grew more numerous and intense as the voltage was raised until a flaming arc appeared. On an ordinary day 55 k.v were requisite for the production of an arc discharge but 35 kv. sufficed on a rainy day. The maximum current before the formation of the arc was more than 20 times as large on a dry day as on a wet one. The change is attributed to the loss of mobility of negative ions in air of high humidity. Elster and Geitel many years ago found that a fog greatly reduces the mobility of gas ions.

When the wires are positive instead of negative with respect to the plates " the corona current flow is greatly reduced and spark discharge sets in at a relatively low voltage even on dry days, so that the action of negative wires on wet days was similar to the action of positive wires on dry days.

G. F. S.

NOTES FROM U. S. BUREAU OF MINES.*

GILSONITE, A DIFFERENT SORT OF MINERAL.

GILSONITE, one of the world's oddest minerals, is mined only in the State of Utah. It is a brilliant, black, asphaltic substance, and is used in the manufacture of varnish, paint, electrical insulation, inks, telephone mouthpieces, electric switch handles, and knobs and buttons of various kinds. The transportation of gilsonite to the consuming public is started over one of the steepest and most crooked railroads in the world, which crosses the Book Cliffs at Baxter Pass at an elevation of 8,437 feet, trains actually traveling 24 miles between points only 6 miles distant by air line.

Gilsonite was discovered in the Ashley Valley in the Uintah Basin, Utah, several years after the first white men settled in the valley in 1878, states W. J. Fene, associate mining engineer, United States Bureau of Mines, in a report just issued. The settlers discovered veins of a brilliant black substance in various parts of the basin. At first this substance was thought to be a variety of coal. When burned, however, it gave off large quantities of dense black smoke with a peculiar odor and instead of reducing to ashes the material melted and drew out into tarlike threads.

The first discovery was probably made in 1862 at what was then called Culmer vein, several miles south of the present site of the town of Myton in Duchesne County.

A study of the substance was made by Professor W. P. Parker. He found that it was a member of the asphalt group and, as it was discovered on the Uintah Indian Reservation, he called it "Uintaite." Samuel H. Gilson became interested in these deposits and spent many years in his efforts to find a market for the Uintaite. His enthusiasm was regarded as more or less wasted by the people of the vicinity and the term "gilsonite" was locally applied to the Uintaite. When Gilson's

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efforts finally developed a market the name gilsonite had become firmly attached to this substance and it is now so known throughout the world.

After more or less successful exploitation of the deposits, involving the hauling of the ore as far as 125 miles to a railroad, in 1902, the demand for the material became so great that better methods of placing it on the market became necessary. The Black Dragon vein was developed, and by 1904 enough ore was accrued to warrant the construction of the Uintah Railway connecting the Dragon Mine with the Denver and Rio Grande Railroad at Mack, Colorado.

Gilsonite occurs in the veins in a solid homogeneous mass and breaks with a conchoidal fracture. Even in the minutest pieces the brilliant fracture is preserved. Long exposure to the weather causes it to lose this brilliant black luster and it becomes dull and black. Occasionally it has a fine columnar structure at right angles to the walls. This is called "pencilated" ore and is frequently found on both sides of the vein. The veins outcrop on hilltops but elsewhere the ore is covered with 15 feet or more of soil.

The surface ore melts at about 400 degrees and is used principally as a saturant of felt in the manufacture of roof and floor coverings. It is generally designated as White Label ore and with increasing depth it gradually becomes better in grade and is termed "select" grade about 50 feet beneath the surface at the Rainbow mine; but in places north of the White River "select" material is not found until a depth of 300 to 500 feet is reached. Select ore will melt at 275 degrees F. and is used in the manufacture of high-grade paints, varnishes, and electric insulation. Although gilsonite lacks any elastic properties, it makes a varnish whose elasticity is remarkable. A thin piece of tin coated with good gilsonite varnish may be bent repeatedly without the coating being cracked.

Gilsonite is closely related to wurtzilite or elaterite and to ozocerite, which is also found in the Uintah Basin. A kindred hydrocarbon, grahamite, is found in Oklahoma. The specific gravity of gilsonite is 1.035, its hardness is 2, and the streak on a porcelain plate is brown. It is exceedingly brittle and during mining gives off clouds of chocolate brown dust which

softens under the heat of the body and is very penetrating to the skin. It is insoluble in water and is removed from the body with difficulty. It is not affected by acids but is soluble in alcohol, turpentine, carbon bisulphite, heavy oils, and fats.

The Uintah Basin, an area of some 15,000 square miles, contains a storehouse of asphaltum, asphaltic sandstone, and oil shale so large that expressed in figures it is staggering. It is estimated that one mile of the Cowboy vein alone, in the widest place, contains about 316,800 tons for each 100 feet in depth, so that the supply of gilsonite seems almost inexhaustible.

Various theories have been advanced as to the formation of these veins. The most plausible theory appears to be in this great synclinal basin gigantic cracks were formed in the brittle and non-elastic sandstone measures of the Uintah formation. Later due to heat the oily matter in these carbonaceous measures was distilled from the underlying Green River shales and deposited in these cracks.

The ore found near the surface contains foreign matter, mostly silica, which renders it unfit for the best trade. It was formerly the practice to leave in the ground as pillars much of this surface ore, but recently the use of this quality of gilsonite for the saturation of felt has increased until it comprises one-half of the gilsonite ore shipped. The growth of foreign use of gilsonite has increased until one-fifth of the ore mined is consumed outside of the United States. The demand for gilsonite in England, France, Germany, Italy, Holland, Belgium, and Japan is steadily increasing.

A very small amount of foreign matter in a shipment of select ore will render it unsuitable for varnish so that the utmost care must be taken to prevent chips of rock or grains of sand from getting into the high-grade ore.

The mining of gilsonite, unlike that of coal or other ores, requires no elaborate surface plants. The ore outcrops at the surface where mining is started and progresses downward, all of the ore of the vein being removed. The gilsonite ore does not have to be prepared and, as it is sacked and made ready for shipment in the mine, the only loading equipment necessary is a platform from which the sacks of ore are transferred from the mine car to railroad cars.

RECOVERY OF RADIUM, VANADIUM, AND URANIUM FROM CARNOTITE.

THE use of a modified nitric acid method for the recovery of radium from carnotite tailings, from which the vanadium has been extracted is suggested by the Bureau of Mines, to prevent the loss of the radium content being wasted in present practice.

The carnotite ores of Colorado and Utah were the chief source of radium for many years. In the fall of 1922 news of the very rich deposits of radium ore discovered in the Belgian Congo caused almost complete cessation of domestic production. The Congo ore contains pitchblende and a number of alteration products, including the newly identified minerals bequerelite, curite, kasolite, stasite, and dewindite. Reports indicate that a considerable amount of ore containing over 50 per cent. uranium oxide has been produced. The price of radium has been held at $70 per milligram. Extraction of radium from carnotite by the usual methods does not appear to be profitable at that price. With one exception, all American firms ceased production after their accumulated stocks of ore had been treated. One company, which continued to treat carnotite for several years, has recently shut down its plant.

Carnotite contains the valuable element, vanadium, which is not present in the Congo ore. The recovery of vanadium is an important factor in the cost of extracting radium from carnotite, and under favorable conditions carnotite can be profitably treated for the vanadium alone. Vanadiferous sandstones are found ranging all the way from roscoelite (vanadium mica), containing little or no uranium, to a high-uranium and low-vanadium carnotite. Ores containing 2 per cent. or more uranium oxide are classed as radium ore and are sold on the basis of the uranium content, which is proportional to the radium content. Only in exceptional cases have ores been evaluated on the basis of both the radium and vanadium contents, although the presence of vanadium has undoubtedly influenced the price of radium ore.

Since the advent of radium from Congo ore, a large quantity of carnotite has been treated for the vanadium alone, the radium being discarded with the tailings. Since the entire cost

of mining, transportation, and milling the ore is thus covered by the value of the vanadium, it seems advisable to ascertain whether the radium and uranium can not also be recovered at a profit, or at least saved in such a concentrated form as to be available when market conditions justify further refining.

Present methods of extracting vanadium from carnotite leave the radium as a fine precipitate in the tailings. The water used to flush these tailings away from the plant and the subsequent weathering may easily disperse the radium-bearing slime beyond possibility of recovery. If, however, the tailings are deslimed and the slimes dewatered and stored, then the radium will be saved in a concentrated condition suitable for subsequent refining; this can be done at a cost which is an insignificant fraction of the former, and probable future, value of such a concentrate. There is also a limited market for such material in the manufacture of so-called medecinal radioactive preparations, which, though reported of doubtful therapeutic value, might better be made from a discarded tailing than from a virgin ore having a still lower radium content.

LUMINOUS PRESSURE WAVES.

Photography of the phenomena taking place when a cartridge of dynamite is detonated has shown the existence of luminous waves propagated at high speed in the air surrounding the explosive. It was at first thought by the Bureau of Mines' investigators that these waves were merely reacting gases projected from the explosive, but further work in which the air around the stick has been replaced by hydrogen or carbon dioxide has made it seem probable that these are really pressure waves at such high temperatures that the gas actually radiates in the visible region of the spectrum. The work is part of a program of investigation of the sensitivity of explosives to detonation by influence.

INDENE AND STYRENE.

In the course of a study by the Organic Chemical Laboratory of the Bureau of Mines of the cause of service gas meter

stoppages it developed that the main cause of the trouble was gum formation from indene and styrene. These compounds are always present in manufactured gas. In freshly made gas they are very volatile and readily carried in the gas stream, but on standing in contact with other gas constituents they tend to "polymerize" or form gums. Gums are thus formed in house meters, making removal of these for cleaning necessary.

A recent survey of the gas industry develops that there are 8 million pounds per year of styrene and twice that amount of indene available if completely removed from the gas. These compounds could be used in the manufacture of plastics. Styrene could be used in the manufacture of perfumes and possibly also in rubber manufacture. It is suggested that here is a field for development of industrial values in these substances which are now admittedly industrial nuisances.

FERROUS OXIDE A METALLURGICAL MYSTERY.

The Pacific Experiment Station of the Bureau of Mines, Berkeley, Calif., in its work on the determination of physical and chemical properties of the oxides of metallurgically important substances, has encountered the problem of preparing pure ferrous oxide. It seems to have been prepared pure by previous investigators only in minute amounts of less than 1/10 gm., whereas samples of several pounds are desired for the usual determinations of specific heats, heats of formation, etc. The oxide is metastable below 500° or 600° C., and must be prepared above and rapidly chilled through this range, even to produce relatively impure material. A common method of preparation has attempted to reduce magnetite by metallic iron. Experiments carried out in a specially designed high-frequency induction furnace of vacuum type, and provided with a specially efficient means of chilling the product, showed that repeated treatments of fused iron oxides with pure iron between the melting point of the oxide and that of the iron, consistently gave only about 85 per cent. limiting purity. This constitution seems to be a steady or equilibrium condition, and the proof that such limits exist has important bearing on certain problems involving ferrous oxide, not only

in connection with the metallurgy of iron, but also with studies of the condition of copper-smelter, slags, and mattes.

THE EXPLOSIBILITY OF VARIOUS COALS.

During the past fifteen years the Bureau of Mines, at its Experimental Mine, has tested mine-sized dust prepared from coal taken from 29 different mines in different parts of the country. These range in composition from the anthracites of Eastern Pennsylvania to the high volatile coals of Utah and Wyoming. The amount of incombustible material required in a mixture to prevent propagation of an explosion under standard propagation test conditions was determined for each coal. It was found that 20 per cent. was sufficient for a coal whose ratio of volatile to total combustible was 0.15 but the quantity increased rapidly with increasing ratio and 61 per cent. was required with coals whose ratio was 0.23. There was then no further increase until ratio 0.40 was passed; that is, a coal having a ratio of 0.40 required 61 per cent. incombustible in the mixture the same as a coal of ratio 0.23. Beyond ratio 0.40 there was a slow increase and 70 per cent. incombustible was required for coals whose ratio was 0.50. It is felt that these limits are known with sufficient accuracy to justify applying them to any coal not tested in the Experimental Mine. Composition is one of six factors which influence the explosibility of coal dust and a paper summarizing the present knowledge of all six is in preparation.

Reflection of Electrons by a Crystal of Nickel. C. J. DAVISSON AND L. H. GERMER. (*Proc. Nat. Acad. Sciences*, April, 1928.) This report continues an investigation the results of which were published in 1927. A crystal of nickel is regarded as made up of small cubes piled one upon the other. The surface on which the electrons impinged was obtained by slicing off a corner of the crystal by a plane at right angles to a diagonal of a cube. Thus an equilateral triangle was produced. The plane in which the electrons were incident was perpendicular to the triangle and passed through a line drawn from its center to one of its apexes. Rows of atoms of the metal lie in the triangle and parallel to it. "We find that under certain conditions a sharply defined beam of scattered electrons issues from the crystal in the direction of regular reflection. This occurs whenever the speed of the incident electrons is comprised within any of certain ranges which change in location as the angle of incidence is varied. Within each of these ranges there is an optimum speed at which the intensity of the reflected beam attains a maximum." Diagrams are shown in which the intensity of the beam of scattered electrons is displayed in different directions. With a proper bombarding voltage the curves of intensity possess very sharp maxima when the reflected beam makes the same angle with the perpendicular to the triangle as the incident beam. "The angles of incidence and reflection are in all cases the same to within half a degree by our scale readings, and this is within the limit of uncertainty of the measurements."

The discovery of regular reflection of electrons from the face of a crystal is of great significance at this time when the wave theory of matter is under discussion. If a beam of electrons and a beam of radiation are reflected in the same way the cause of this common effect is to be sought in the common structure of the two beams.

G. F. S.

THE FRANKLIN INSTITUTE.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting held Wednesday, June 6, 1928.)

HALL OF THE COMMITTEE,
PHILADELPHIA, June 6, 1928.

DOCTOR GEORGE S. CRAMPTON, *in the Chair.*

The following report was presented for final action:

No. 2872: Pendulum Hardness Tester.

The subject of this investigation includes a new method of measuring the hardness of materials and a new form of apparatus by the use of which the measurement can be carried out. While the method of making an indentation in the surface of the material under test is similar to that employed in other hardness testers the manner of making the indentation and of measuring its amount are new.

The indentation is made by a steel ball 1 mm. in diameter to which a known weight is applied. This weight consists of an inverted U-shaped piece of metal which carries the ball in a central chuck, the proper adjustment being such that the center of gravity of the weight nearly coincides with the center of the ball.

This constitutes a compound pendulum having a large moment of inertia and a very short length which is adjusted so as to bring the period of oscillation to ten seconds for a single swing, when the ball rests upon a horizontal glass surface.

When the instrument is set upon the surface of a softer material the swinging of the pendulum is affected in two ways: first, its swings are dampened; second, its period of swing is shortened. These two effects constitute two distinct means of measuring hardness. The dampening effect gives data for the Scale Hardness Test and the change in the period of oscillation gives data for the Time Test. The Time Test may be described as a measure of indentation hardness and the Scale Hardness Test is a measure of resistance to flow.

The recommendation to award the Edward Longstreth Medal to Mr. Edward G. Herbert of Levenshulme, England, in consideration of his technical ability in the development of this unique method and the instrument for putting it into effect and the contribution he has made to the general knowledge of the subject of the hardness of metals, was adopted.

The following reports were presented for first reading:

No. 2875: Ruths' Steam Accumulator.

No. 2893: Gas Carburizing Apparatus.

GEO. A. HOADLEY,
Secretary to Committee.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, June 13, 1928.)

RESIDENT MEMBERSHIP.

COLONEL JAMES H. M. ANDREWS, Assistant to the President, Philadelphia Rapid Transit Company, Mitten Building, Broad and Locust Streets. For mailing: 7208 Lincoln Drive, Philadelphia, Pa.

MR. EDWARD W. BURNSHAW, JR., Automotive Business, 245 North Broad Street, Philadelphia, Pa.

MR. A. LESLIE LAMBERT, Secretary, Chief Engineer, Heintz Manufacturing Company, Front and Olney Avenue, Philadelphia, Pa.

MR. DAVID F. REILLY, Medical student, 235 North Eighteenth Street, Philadelphia, Pa. For mailing: 617 Main Street, Dickson City, Pa.

NON-RESIDENT MEMBERSHIP.

MR. HERBERT A. ERF, Acoustical Engineer, 407 Permanent Homes Building. For mailing: 11851 Lake Avenue, Suite 21, Lakewood, Cleveland, Ohio.

DR. LEONARD B. LOEB, Associate Professor of Physics, Department of Physics, University of California, Berkeley, California.

DR. FRANK N. SPELLER, Director—Department of Metallurgy and Research, National Tube Company, 1810 Frick Building, Pittsburgh, Pa.

CHANGES OF ADDRESS.

LUCIUS B. ANDRUS, Esq., Indianapolis Athletic Club, Indianapolis, Indiana.

MR. JOSEPH S. BENNETT, 3D, 274 Forrest Road, Merion, Pa.

MR. ROLAND B. DAY, The Day Petroleum Corporation, 30 Church Street, New York City.

MR. WILLIAM DUBLIER, Dublier Condenser Corporation, 10 East Forty-third Street, New York City.

MR. HUGH S. GORDON, Tati Company, Ltd., Francistown, British Bechuanaland, South Africa.

MR. WILLIAM STEELL JACKSON, 1011 Chestnut Street, Philadelphia, Pa.

MR. CHARLES F. KELLERS, 759 West Washington Avenue, Jackson, Michigan.

MR. W. E. MOORE, President W. E. Moore and Company, Engineers, Foot of Thirty-second Street and Putney Way, P. O. Box 1125, Pittsburgh, Pa.

DR. ALFRED OBERLE, 842 New York Life Building, Kansas City, Missouri.

CAPTAIN E. R. WOOD, JR., Room 607 Provident Trust Building, Seventeenth and Chestnut Streets, Philadelphia, Pa.

MR. W. M. KERR, Packard Building, Fifteenth and Chestnut Streets, Philadelphia, Pa.

LT.-COL. CHESTER LICHTENBERG, 300 Strathmore Road, Brookline, Upper Darby, Pa.

MR. FRANK S. MACGREGOR, Twenty-third Floor, 2 Park Avenue, New York City.

MR. F. M. MURPHY, 209 South New Hampshire Avenue, In care of J. V. Lehigh, Esq., Los Angeles, California.

MR. W. S. MURRAY, 369 Lexington Avenue, New York City.

DR. SAMUEL E. POND, Woods Hole, Mass.

NECROLOGY.

Mr. Thomas J. Dolan, Villa Nova, Pa.

Dr. I. P. Lihme, Cleveland, Ohio.

LIBRARY NOTES.

Recent Additions

ABEGG'S Handbuch der anorganischen Chemie. Vierter Band, dritte Abteilung, erster Teil. 1928.

American Electrochemical Society. Transactions 1927. Volume 51. 1928.

CHAMBERLAIN, JOSEPH SCUDDER. A Textbook of Organic Chemistry. 1928.

CREW, HENRY. The Rise of Modern Physics. 1928.

DAVIS, A. H., AND G. W. C. KAYE. The Acoustics of Buildings. 1927.

GOLDSCHMIDT, VICTOR, AND SAMUEL G. GORDON. Crystallographic Tables for the Determinations of Minerals. 1928.

History of Science Society. Sir Isaac Newton, 1727–1927: a Bicentenary Evalua tion of his Work. 1928.

KEEN, R. Wireless Direction Finding and Directional Reception. Second enlarged edition. 1927.

MACINTIRE, H. J. Handbook of Mechanical Refrigeration. 1928.

MARSHALL, C. F. DENDY. Two Essays in Early Locomotive History. 1928.

MOTTELAY, P. FLEURY. Life and Work of Sir Hiram Maxim. 1920.

OLLIVER, C. W. The A.C. Commutator Motor. 1927.

PALMER, L. S. Wireless Principles and Practice. 1928.

POMEY, J. B. Cours d'Électricité Théorique. Tome I. 1914.

QUAERIS, Q. M., AND OTHERS. Notre Misère Scientifique: ses Causes—ses Remèdes. L'Appel du Roi. 1928.

Society of Chemical Industry. Reports of the Progress of Applied Chemistry. Volume 12, 1927.

TURNBULL, ARCHIBALD DOUGLAS. John Stevens: an Americal Record. 1928.

WALTON, ROBERT P., Editor. A Comprehensive Survey of Starch Chemistry. 1928.

WEISER, HARRY BOYER. The Hydrous Oxides. 1926.

WIEN, W., AND F. HARMS, Editors. Handbuch der Experimentalphysik. Band 19. 1928.

WILCOX, EDGAR A. Electric Heating. 1928.

WILSON, WILLIAM. Electric Control Gear and Industrial Electrification. 1927.

BOOK REVIEWS.

THE CHEMICAL EFFECTS OF ALPHA PARTICLES AND ELECTRONS. By Samuel C. Lind, Ph.D., Director of the School of Chemistry, University of Minnesota. Second (revised and enlarged) edition. American Chemical Society Monograph Series, Number 2. 252 pages, 42 tables, 13 illustrations, cloth, 8vo. New York, The Chemical Catalog Company, Inc., 1928. Price, $5.

That the subject of this volume represents a live and rapidly growing division of experimental and theoretical science, may be realized fully from a comparison of the first and second editions. In the six years which have elapsed between the issuance of the first and second editions sufficient additional information has become available to make this monograph one-half as large again.

Doubtless, there are but few who can realize and appreciate the full significance of these recent discoveries and fewer still who would dare to predict the status of this subject six years from now. As in all branches of scientific investigation many difficulties have been encountered and are being overcome, one by one, by dint of brilliant thought and plenty of hard work.

That the chemical effects of alpha particles and electrons may be investigated with any degree of success a satisfactory source of radiation is imperative. As a source of alpha-particle radiation radium-C and radium-F (polonium) have been utilized to advantage. Yet, their relatively short periods of existence have made impossible any sustained investigation of their chemical effects. Until recently no constant source of electron (beta particle) radiation has been available. However, this problem has been solved ingeniously by Dr. Coolidge of the General Electric Co., who, has developed a tube which will produce electronic radiations of controlled intensity and make them available for experimental purposes. So far the effects produced by this beta ray (particle) radiation have been studied only in a qualitative way. Such phenomena as already observed, indicate that in the near future these rays will play an important part not only chemically but also physiologically and therapeutically.

In studying the chemical effects of these radiations both qualitatively and quantitatively the chemist must adopt a specialized technique already acquired by the physicist who has been studying intensively the physical properties of these radiations for three or four decades.

There seems to be no doubt but what continued investigation in this field will disclose many fascinating problems. Already anomalies in the predicted behavior of the various reactants have been observed and organic compounds of unsuspected constitution evolved.

A very comprehensive perspective of the widespread advances in the field of radiochemistry during the past six years may be obtained from the author's preface to the second edition. The progress accomplished in this sphere has necessitated the addition of seven new chapters and an extensive revision of the others. New discoveries have added support to the theory of reaction mechanism in ionized gases and emphasized the idea of ion clustering. The work of Mund on the development of a general equation for calculating gas ionization by radon in spheres is outstanding. Results obtained in the investigation of the catalytic influence of foreign gases make necessary a broader view on the probability of electron exchange, while the determination of the size of effective ion clusters in different gaseous systems looms up as perhaps the most outstanding problem at the present time.

The first chapter, "Radiochemistry," has been enlarged by a paragraph on the utility of the Einstein law of photochemical equivalence. In addition the author has defined the term radiochemistry, outlined the field embraced by it and shown its relation to that branch of the study known as photochemistry. Chapter two contains a brief outline of radioactivity and some properties of the radiations. Such knowledge concerning the radioactive series of elements is necessary if the reader would have a clear understanding of the controlling factors in the various experiments to be described later. Chapter three deals with the electrical effects produced by the various radiations, alpha, beta, gamma and X-rays and the general characteristics of gaseous ionization. A paragraph

on the relation between beta and gamma rays has been added. Chapter four, "Qualitative radiochemical effects," has been largely rewritten and contains much new material. The author arbitrarily classifies radiochemical investigations under eight headings depending upon the amount of definite knowledge available. A timely paragraph on precautions in sealing radium salts has been inserted. Radium sealed in small tubes for a considerable length of time has caused the tubes to explode with a resultant loss of its valuable contents. A far-reaching disintegration of quartz containers has been reported and pyrex containers also have been found to be unsuitable for radium solutions. Other topics dealt with in this chapter are the luminescence of radium salts, the coloration of glass and minerals, thermo- and photo-phosphorescence and the discharge of color, constant light sums of thermo-phosphorescence, etc. The paragraph on luminescence and phosphorescence produced by radiation is particularly interesting containing as it does an exposition on the preparation and properties of luminous paints. Chapter five deals with chemically quantitative investigations in liquid systems and includes a study of the decomposition of water by radium salts in solution, the formation of hydrogen peroxide in water and reactions produced by penetrating rays. The effects of the penetrating rays have been studied extensively by Kailan and included such things as the decomposition of the alkaline and rare earth iodides, the reduction of ferric sulphate, the inversion of cane sugar, the conversion of nitrobenzaldehyde into nitrobenzoic acid, the action on chloroform and carbon tetrachloride and the oxidation of toluene. In some of these experiments a comparison was made with ultraviolet radiation which produced similar effects one hundred to one thousand times as rapidly. Chapter six contains a description of the first experiments upon the reactions produced by radon. These consisted of the decomposition of carbon monoxide, hydrogen chloride, ammonia, and the decomposition of water as well as the combination of hydrogen and oxygen both dry and moist. Considerable work also has been done on the equilibrium between hydrogen, nitrogen and ammonia. Considered in the light of experimental technique and the application of theoretical knowledge chapter seven is no doubt the most important in the book. It begins with an outline of the historical development of the ionization theory of the chemical effects of corpuscular radiation. This is followed by a paragraph on how to construct and use an alpha-ray bulb, the calculation of ionization from such a bulb and the purification of radon to be used in the bulb. The development of an equation for calculating the average path of alpha particles in a sphere is clearly described. This is followed by an equation for the calculation of ionization of radon in small spheres and a detailed description of Mund's equation for calculating ionization by radon in large spheres. This chapter also contains an exceedingly valuable and comprehensive table giving a comparison of the chemical action and ionization by alpha particles. Chapter eight occupies itself with a development of a general kinetic equation for the action of radon when mixed with gases in small volumes and the application of this equation to experimental results. Chapter nine, "Chemical effect of recoil atoms" corresponds to the latter part of chapter eleven in the first edition. A comparison of the absorption of alpha rays and recoil atoms is made; the latter's general properties, chemical reactions described and the results of later experiments outlined. Chapter ten on additional relationships of the radiochemical effects discusses

the influence of varying the proportions of reactants, the action of alpha rays on pure oxygen, activity of gaseous hydrogen ions, energy utilization of alpha rays in chemical reactions and includes a general discussion of ionic-chemical equivalence. Chapter eleven deals exclusively with what is known as the M/N ratio or the relation of chemical reaction to ionization. Chapters twelve to fifteen inclusive deal with the effects of radiation upon saturated one-component systems, unsaturated one-component systems, oxidation in two-component systems and hydrogenation in two-component systems respectively. An excellent summary of the material is given by the table in chapter seven as mentioned above. Chapter sixteen on the catalytic effect of ions of inert gases deals with some of the more recent investigations in this field. In general, the presence of an inert gas has caused an acceleration in the reaction produced by the radiations. The mechanism of these catalytic ion reactions has been a source of speculation and at present is believed to involve an exchange of electrons between the molecules of inert gas and those of the reactants. A chapter (seventeen) on the chemical effects of electrical discharge in gases is certainly not amiss in a book like this. Investigations in this sphere seem to have been more or less incidental and have resulted in a great variety of phenomena being recorded. The ionization theory has been applied to these electrochemical effects in gases more or less successfully. Chapter eighteen contains an elucidation of the law of photochemical equivalence and a comparison with ionic-chemical equivalence. The relation between the two is striking. So far this book has dealt with the effects produced by the alpha rays colliding with the electrons of the atoms or molecules. However, an occasional alpha particle will collide with the nucleus of the atom and cause a disruption of the latter. The book would not be complete without the last chapter which outlines the research done on the atomic disruption by alpha particles. The author critically examines the results of these investigations which are of comparatively recent origin. The appendix consists of tables giving the decay of radon, conversion factors, ordinary isotopes of the elements, list of radioactive isotopes by groups, Mund's factor for the efficiency of ionization by radon in spheres and a list of papers by the author and his collaborators respectively. The book contains both an index of authors and of subjects.

Dr. Lind has done a splendid piece of work in the rewriting and revision of the first edition of his book. When the abundance of widely scattered and seemly unrelated data concerning this subject is taken into consideration, then it will be realized just how difficult it must have been to evolve a system of classification such as this book embodies.

THEODORE K. CLEVELAND.

THE METHODS OF ORGANIC CHEMISTRY. A LABORATORY MANUAL. By C. W. Porter, T. D. Stewart and G. E. K. Branch, Members of the Faculty of the College of Chemistry in the University of California. iv–311 pages, 8vo., illustrated. Boston, Ginn and Company, 1927. Price, $2.

The authors make very modest claims in regard to the rôle this book is supposed to fill in the study of organic chemistry. They have started out with the expressed intention to prepare an outline providing material for a laboratory course in organic chemistry. When they finished they had a manual which not only students but those doing research will find to be of inestimable value as a

reference volume. This book, which was designed to meet the requirements of either the usual short course in organic preparations, or of a full-year course is composed of five parts. Part I and experiments selected from Part II constitute the subject matter for a half-year course while the system of qualitative analysis as outlined in Part III constitutes material for a second half-year's work. Part IV is a very complete discussion on acids, bases and indicators, while Part V is a description of the methods used in quantitative analysis of organic substances.

Part I, "Mechanical Operations," clearly describes the latest approved technique as applied to experimentation in organic chemistry and is well supplied with illustrations of the necessary apparatus. The first subject dealt with and one of primary importance is distillation. The physical chemistry of vapor pressures of pure liquids and their mixtures has been inserted in order to give the student some idea as to the why and wherefore of such procedure. The process of extraction is treated from the viewpoint of the partition coefficients of solvents and placed upon a more or less quantitative basis. The chapter on the determination of the boiling point includes instructions for the correction of boiling points and a list of constants for some of the more common liquids. The various methods of drying are considered in quite some detail and are accompanied by a table giving the vapor pressures of various drying agents. Other subjects discussed in this first part are filtration, crystallization, sublimation, determination of the melting point and the calibration and use of thermometers. If the student or researcher should desire to apply various other physical methods he will find at the end of the section a bibliography for such methods as optical rotation, absorption spectrum, boiling-point and freezing-point determinations, refractive index, colorimetric and microscopic analysis, magnetic rotation, determination of hydrogen ions, etc.

Part II, "Organic Preparations," starts out with exercises in distillation and crystallization, this is followed by a description of the methods used in qualitatively testing for the elements and includes equations for the principal reactions involved. The remainder of the section describes the preparation of over fifty organic substances involving most of the well-known methods of organic synthesis. A list of questions for review also is included in this section.

Part III, "Class Reactions," is a system of organic qualitative analysis. The authors have divided the organic substances into various classes and described those reactions peculiar to the members of each class. Their method of accomplishing this is very commendable in that they lay particular emphasis upon the probable mechanism of the reactions and the intimate relations between such reactions and the structure of the compounds involved. The whole system is logically laid out and the worker reaches his objective through a process of elimination.

Part IV, "Acids, Bases and Indicators," considers acids and bases from the standpoint of their ionization constants or the extent to which they ionize in solution. The nature of indicators is discussed on a similar basis. The titration of acid and bases and the determination of equivalent weights is dealt with in great detail. A graph is given having hydrogen ion concentration plotted against equivalent weight and clearly shows why one indicator is more suitable than another in a particular titration. Considerable stress is laid upon the possible error in end-point of titration, the percentage error and erratic errors.

Part V, "Quantitative Analysis," contains a description of the well-known methods for quantitatively determining the amount of carbon, hydrogen, oxygen, nitrogen, sulphur, or halogen in organic compounds. Following Part V is a list of over one hundred problems for review. The appendix consists of tables giving the vapor pressures of water and such organic liquids as methyl and ethyl alcohol, ether, acetone, benzene, chloroform, carbon tetrachloride, and carbon bisulphide; a list of the elements with their atomic numbers and weights; the vapor pressure of aqueous potash hydroxide solutions and methods of preparing various indicators and reagents.

The authors have produced a book which is noteworthy for its completeness of detail and clarity of description. The book is something more than an ordinary laboratory manual since it contains much information of value to the advanced student and research chemist. THEODORE K. CLEVELAND.

ELECTRIC CONTROL GEAR AND INDUSTRIAL ELECTRIFICATION. By William Wilson, M.Sc., B.E., M.I.E.E., A.A.I.E.E. xiii–361 pages, 21 x 14 cm., cloth. New York, Oxford University Press, American Branch, 1927. Price, $8.50.

The adaptability of the electric motor drive to any and every kind of machine is now generally accepted as a matter of course. The rise of electric motive-power is due to several independent factors. Next in importance to the motor itself, one of these is the perfecting of the several auxiliaries known as the electric control gear whereby the combinations of contacts which control the passage of current in accordance with a predetermined plan and method of operation are made and broken. For small powers and fixed speeds the matter is a relatively simple one, but with variable speeds, large powers, remote and sometimes automatic control, the problems that arise in providing mechanisms which will perform such functions with certainty demand the closest study on the part of the designer. The author, in presenting an account of the multiplicity of functions of the power-current in the motor circuit and the devices by which they are controlled, has gathered an extensive collection of typical apparatus adapted to a wide variety of applications in which considerable or large quantities of power are consumed.

Since the characteristics of the motors to be controlled and the power which they are required to deliver are leading elements of the subject, the author prefaces the consideration of the various types of control equipment with a brief review of the capabilities and peculiarities of the chief forms of motor employed in industry. That done, the principal topics of the discourse are considered in detail. Among these we have first, chapters on manual starters and controllers, resistance control and multiple-voltage and series-parallel control followed by a chapter on methods and devices employed for starting squirrel-cage and synchronous motors. Solid resistors and liquid rheostats each have a chapter. Those devices which may be classified generally as relay systems and their details are given three chapters with an additional chapter on the methods of laying out the constituent elements of control systems. Electric braking and motor-generator control systems complete the treatment of the details of the control gear.

The subsequent chapters describe the characteristics of the electric operation of factories in general and more specifically the equipment and control apparatus for electric elevators, rolling mill and other mill motors, furnace and mine hoists,

electric cranes, machine tools. Each of these is given a chapter and there is a final chapter on control gear for the operation of machines not included in the classes above mentioned.

Of electric control gear there is already quite a comprehensive literature on American practice but this work deals also in a large measure with the entire installation. On both of the divisions specified in the title, the book contains a large amount of practical data in a convenient form as well for reference as for systematic study of the electric power equipment of factories.

LUCIEN E. PICOLET.

HANDBUCH DER ANORGANISCHEN CHEMIE. By R. Abegg, F. Auerbach and I. Koppel. Band IV, 3, 1 Teil. Die Edelgase, by Dr. Eugen Rabinowitsch. 522 pages, illustrations, 8vo. Leipzig, S. Hirzel, 1928. Paper cover, 45 marks; bound 48 marks.

The series to which this volume belongs has established itself among the foremost treatises on inorganic chemistry. The whole work has been characterized by comprehensiveness and accuracy. The literature has been thoroughly sifted and the data well arranged. The volume in hand has somewhat more than ordinary interest, for some of the romance and tradition of chemistry is involved. The term "noble gases" takes us back to the alchemists and even beyond. The indifference of gold and silver to the common corroding agents was evident and impressive. It might be worth while to speculate on what would have been the reaction of the ancients to platinum. Their inability to melt it and the ease with which it can be alloyed with the baser metals might have been puzzling. The classification in this volume puts the gases of the helium group as the eighth period of the periodic system, but many tables place the series first. The difference is not important. Of all the members of the series, helium interests us most. Recognized originally in the chromosphere of the sun and, for a while, presumed to be an element beyond our reach, it has become quite familiar, and is obtainable in considerable quantities. The United States has, so far as known at the present time, the largest supply, and people in many parts of the country are familiar with the fish-like bag of the dirigibles floated by it. Its production by the disintegration of uranium has also a most important bearing upon the basic principles of chemistry.

As is well known, the first of the series discovered was argon, which had been for a long while overlooked in the air, although present in decidedly appreciable proportion. Its indifference to chemical action made it at the time of its discovery an exception to general elementary rule and earned its name. Krypton, xenon and neon are now also known. Neon has become very familiar from its large use in display signs on account of its strong red emission under electric discharge.

It is to be regretted that Lockyer assumed that the element which gave the bright yellow line near those of sodium was a metal, for the proper name is "helion," but there is little hope of a change generally among chemists. A curious feature of the history of helium is the confusion in the bibliographies that have been published and the fact that there seem to be no definite data as to when and by whom the element was named. The author of this volume ascribes the naming to Lockyer and Frankland, but in 1894, Lockyer said in a

lecture that he coined the name as a laboratory term, presumably to avoid frequent periphrases. In several of the bibliographies of helium the name of Frankland has been improperly joined with that of Lockyer; Janssen also has been given credit which does not seem to belong to him.

It is interesting to compare the volumes of this series with the work that appeared under the authorship of Gmelin. The latter was in its day a monumental contribution to chemistry, and in spite of the vast increase of data and the extensive changes in theory that mark the intervening years, Gmelin's volumes are still worth consulting in many cases.

Concerning the specific character of the volume in hand it is merely necessary to say that it sustains the reputation of its predecessors and presents a splendid study of the chemistry of the curious and important group of gases of indifferent chemical affinity. The publisher has issued it in excellent form with clear, easily read type, good paper and presswork. It constitutes an epoch-making contribution to the literature of inorganic chemistry.

HENRY LEFFMANN.

A COMPREHENSIVE SURVEY OF STARCH CHEMISTRY, Volume I. Compiled and edited by Robert P. Walton, with numerous collaborators. 360 pages, illustrations, 8vo. New York, The Chemical Catalog Company, Inc., 1928. Price, $10.

Starch is an interesting carbohydrate. Throughout the vegetable kingdom it occurs very frequently, especially in roots, tubers and seeds. Through its capacity to be converted rapidly and easily into sugars it becomes the basis of a very large number of industries especially the fermentation industries which bring the chemist in contact with problems that are related to society and to conduct. The changes that occur in starch are mostly through the influence of enzymes, those peculiar nitrogenous bodies which have the power to produce a very large amount of chemical action without being themselves exhausted in the process. They are somewhat like the initiators of our modern high explosives. In fact starch itself might be compared to a high explosive, though the products of its explosion are mild forms of energy. The source of starch in the vegetable kingdom has been the subject of a good deal of investigation and some speculation which is based perhaps more upon hope than upon absolute proof. A very simple chemical reaction between carbon dioxide and water resulting in the elimination of oxygen will give us starch, but the problem has been to account for such a reaction inasmuch as it is accompanied by the absorption of energy while the majority of chemical reactions liberate energy. The generally accepted explanation which seems to be well founded, indeed might be considered as proved, is that the energy is that of light. Starch in itself of course does not exhibit any energy; it does not radiate it as radium does, but it can be decomposed with considerable energy liberation. It is dangerous to speculate upon the deeper principles of organic chemistry as applied to vital action but it seems that starch is a provisional storage so that the plant may use it at the proper time. Starch is insoluble in cold water and therefore is not readily subject to the attacks either of enzymes or microbes. A root or a tuber or a seed may thus hold for a long while the starch somewhat as a loaded shell or a cartridge may hold its explosive. If the carbohydrates of the plant were in the form of sugars or of

some of the nearly allied compounds soluble in water, they would rapidly become the prey of enzymes and microbes and would be decomposed. The form of starch therefore acts as a storage, under conditions of dryness, for an indefinite time.

The present volume is not taken up with the more abstruse questions in regard to starch. It deals with the material as a chemical in its varied uses. Nineteen topics are included, among which we may note as especially interesting the rôle of starch in bread making and starch in the fermentation industries. Its application to the development of adhesives is also an important feature. All the topics are in fact of high practical value. A historical note on the early development of starch chemistry concludes the descriptive part of the volume. The remainder of the book, more than half of it, is taken up with an elaborate detailed bibliography covering the literature from 1811 to 1925; facts about starch prior to the earlier date are treated in the historical chapter just noted. Patent literature is not included in the bibliography but a survey of it is in hand and the data will appear in a later volume. The work is illustrated and constitutes indeed a very excellent contribution to the industrial applications of a highly important and widely employed product of the vegetable kingdom.

HENRY LEFFMANN.

SIR ISAAC NEWTON, 1727–1927. A BICENTENARY EVALUATION OF HIS WORK. Prepared under the auspices of The History of Science Society in collaboration with several other scientific societies. Edited by F. E. Brasch. ix–351 pages, portrait, 8vo. Baltimore, The Williams and Wilkins Company, 1928. Price, $5.

It has fallen to many famous persons to have legends attached to their names which, though often frivolous, seem to be inerasable. George Washington has never got rid of the story of the cherry tree and Caesar has always had with him "Veni, vidi, vici." Similarly we are apt to think of the dropping of an apple when the name of Newton is mentioned. The story, like many other of these legends, appears much later than the event, occurring in an indirect relation. It does not seem likely that this was the starting point in Newton's thought on the great question of the general attraction of matter. Physicists, it may be remarked, have not been unanimously satisfied that the force that draws masses together is really an attraction. There have been speculations that at least the apparent attractions of the planets may be due to pressure, but at any rate the theory of Newton has dominated astrophysics for several centuries and its terminology is still used in the science.

The present work is a bi-centennial celebration of the birth of Newton, recording not merely his researches and writings but a critical estimation of the same. He was a puny infant whose life was more than once despaired of in its early period and it was fortunate that in those days, when so little was known about diseases and treatment, he weathered the storm of infancy and was preserved to an active life in the service of science. In addition to the legends which as noted above attach to the biographies of famous men, we often find that useful activity in one direction is overshadowed by other activities, thus preventing full appreciation of the man's work. George Washington, for instance, is famous as a general and as the organizer of the American union. Few know how active he was in engineering work, how much at heart he had the question of trans-

portations from the Mississippi Valley to the seaboard and how he labored to secure legislation to authorize transportation systems and capital to develop them. In no part of his life do we see any greater degree of forward-looking spirit and of appreciation of the importance of inter-state traffic to the solidarity of the American union than in his engineering work. Similarly it may not be generally known that Sir Isaac Newton had a great deal to do with another very important problem in the affairs of a nation, namely the stabilizing of the currency. During the confusion in England in the reign of the Stuarts with the breaking of conditions under the Cromwellian administration, the metal coinage of the realm had fallen into very unsatisfactory conditions. The "clipping" and "sweating" of it were extensively practiced with the result that the market value of the coins was very much out of accord with their stamped value. In such cases the poorer classes suffer almost exclusively. In the reign of William III "of blessed memory," Newton was made master of the English mint and under his supervision the silver coinage of the realm was reformed. The milling of the edges prevented the "clipping" and the sharpness and distinction of the stamping interfered with the practice of "sweating." As Macauley says, it was a new era when these silver coins "bright, heavy and strongly milled" came from the mint. In the collection of the Historical Society of Pennsylvania there is a receipt for bullion received at the Royal Mint signed by Newton.

Apart from his work on gravitation, we find another epoch-making discovery when he passed the light from an opening in the window of a dark room through a prism and saw the spectrum. Had the Greek philosophers made this experiment, they would not have been so puzzled to account for the hues of the rainbow. The aperture which Newton used was much too large to give him the real analysis of light. Long after Wollaston, by using a narrow opening, saw that the spectrum was not continuous and still later Fraunhofer mapped a few of the lines which now bear his name.

The many-sided character of Newton's mind is exemplified in his work in the higher mathematics and by contrast his interest in religious questions. It is rather uncommon now-a-days that the professional scientist of high rank takes interest in dogmatic religion or even in its ethical side. Such questions are usually put aside with consent as to the general propositions and the feeling that one's clergyman can look after the details.

The reading of this volume will be a most useful instruction to beginners in science for it will show them the basic objects of science study. It comes from the well-known Williams and Wilkins Press and sustains the reputation of the corporation and its motto.

HENRY LEFFMANN.

CRYSTALLOGRAPHIC TABLES FOR THE DETERMINATION OF MINERALS. By Victor Goldschmidt (Heidelberg) and Samuel G. Gordon (Philadelphia). 70 pages, 8vo. Special Publication No. 2, The Academy of Natural Sciences of Philadelphia, 1928. Price, $1.50.

Comprised within a small volume is an immense mass of information concerning minerals. Every distinct species known up to the date of the preparation of the book is included. The information is given in much detail. With the proper apparatus it is possible with this work to determine the nature of every

mineral. The tables include the specific gravity, composition, hardness, crystallographic data and brief descriptions of general properties. The printing is very clear, the numbers very distinct and the paper excellent. The work does not begin to show to the ordinary reader the vast amount of labor which has been expended upon it, but its service to the mineralogist will be very great. Both authors are now well-known in connection with mineralogy. The portion containing the statistical data is preceded by a brief introductory article.

HENRY LEFFMANN.

ELEMENTS OF OPTICS. By Joseph Valasek, Ph.D., Associate Professor of Physics, University of Minnesota. xiii–215 pages, 20 x 14 cm., cloth. New York, McGraw-Hill Book Company, Inc., 1928. Price, $2.

If modern physical research has given us new views on the constitution of matter, the manner in which the transfer of energy is effected and new conceptions of space and time, the influence of these new views has not yet changed the general plan of text-books of physics, and with the exception of refinements incident to modern progress and the supplementary treatment of the quantum theory, atomic physics and relativity, the subject is still presented as in the day of that fine old book, Ganot's Physics, so much in vogue during the latter part of the past century. As the author states the matter, ". . . the inclusion of these subjects must not be at the expense of the older and well-established fundamental principles. It is aimed in this text to preserve a proper balance between the old and the new in optics. . . ." The work accordingly covers the topics which are embraced in physical and geometrical optics with those relating to spectral phenomena, radiation and the recent concepts of matter, space and time reserved for the final chapters.

As is to be expected in a condensed course, the different methods which are available of studying various phenomena cannot be analyzed at length. Nevertheless they are very satisfactorily explained, and illustrated with excellent diagrams. Much ground is covered by the application of algebraic and trigonometric method and the use of graphic diagrams which now-a-days are understood by every serious reader. Laws which cannot be so derived are stated without derivation but with understandable explanation of their import. There is little choice in the quality of the presentation of the various topics, the work is indeed very well balanced, but especial mention may be made of the lucid and practical treatment of geometrical optics especially as applied to lenses. Many readers to whom bibliographical references in a book of this kind are of decided value will regret the omission of that feature. The work constitutes a sound and practical exposition of the principles of optics with the least possible mathematical attainment.

LUCIEN E. PICOLET.

NOTRE MISÈRE SCIENTIFIQUE, SES CAUSES, SES REMÈDES, L'APPEL DU ROI. Par Q. M. Quaeris et des collaborateurs. 56 pages, 25 x 16 cm., paper. Bruxelles, Etablissements d'Imprimerie Fr. Saey, Editeur, 1928.

The general appraisement of the condition of a public institution which falls short of meeting rightful expectations is always a logical first-step towards establishing normal functioning; it is the diagnosis which precedes remedial measures.

No less a personage than the King of the Belgians, at the celebration of the centenary of the celebrated Cockerill establishment at Seraing on the 1st of October, 1927 calls the attention of his countrymen to the necessity of according to Science an honored place in their land. The appeal has been promptly heeded. The Counsel of Administration of the Hoover Foundations for the development of the Universities of Louvain and Brussels held a meeting to consider the crises through which higher education and particularly advanced research is passing in Belgium.

The principal object in the issue of this work is to analyze in detail the causes of this lack of vigor in the progress of pure science. The author points out the small earning power of intellectuals due to the lack of balance of public appreciation of the value of cultural achievements against those of more direct appeal to the public mind. Other causes, notably bureaucracy and official prejudices, are noted and, in particular the trying experience of a well-known author of several important contributions to the literature of physical science in his efforts to obtain recognition in educational circles. Though primarily of local interest, the work is suggestive of the condition which may occur elsewhere and to a certain extent does occur elsewhere. It is a document that may well be commended to the thoughtful consideration of educational and administrative officials.

LUCIEN E. PICOLET.

WIRELESS PRINCIPLES AND PRACTICE. By L. S. Palmer, M.Sc., Ph.D., F.Inst.P., A.M.I.E.E., Head of the department of pure and applied physics, Victoria University of Manchester, Late radio engineer to the Admiralty. xi–504 pages, 21 x 14 cm., cloth. New York, Longmans, Green and Company, Ltd., 1928. Price, $7.

When wireless broadcasting first became available to all who cared to purchase or build a receiving set, there was little definite information in print to guide them. But the rapid and vigorous growth of the radio art has quickly resulted in the appearance of rational works in which the subject is treated in its multiplicity of detail as a definite engineering problem; engineering practice based upon low-frequency alternating current principles cannot be applied to problems concerning high frequency currents. The present treatise is especially well adapted to the needs of electrical engineers who wish to become conversant with wireless practice or for other serious readers who desire a rational and deductive exposition of the subject. A knowledge of the elements of electricity and magnetism and of alternating currents and with the mathematics employed in such treatises is essential to a wholly satisfactory perusal of this work, though the results formulated and liberal qualitative information are within the reach of others not so fully equipped.

A very complete survey of the subject is made. Beginning with a consideration of the general theory of wave motion and its application to the study of electromagnetic waves, a detailed study is made of the oscillatory circuit in terms of its essential components, inductance capacity and resistance. In proper sequence, the theory of the thermionic tube, methods of generating high frequency alternating currents by the tube oscillator and other methods are analyzed at length. Then comes a mathematical discussion of the electromagnetic theory and the propagation of wireless waves according to the methods of Maxwell. Detection and amplification are each given a comprehensive chapter. The two

final chapters on wireless cover in ample measure theoretical considerations and current practice of the devices and their auxiliaries which are included under these topics. Some of the features of value which may be noted are the well-executed and convincing diagrams, the ample bibliographies with each chapter and the excellent balance between the discussions of the theoretical and practical aspects of the subject. LUCIEN E. PICOLET.

PUBLICATIONS RECEIVED.

The New Reformation from Physical to Spiritual Realities, by Michael Pupin. 273 pages, portraits, 12mo. New York, Charles Scribner's Sons, 1928, price $2.50.

The Elements of Industrial Engineering, by George Hugh Shepard. 541 pages, illustrations, plates, 8vo. Boston, Ginn & Company, 1928, price $4.80.

A Textbook of Organic Chemistry, by Joseph Scudder Chamberlain, PhD. Second edition revised. 901 pages, 12mo. Philadelphia, P. Blakiston's Son & Co., 1928, price $4.00.

Storage Batteries, Theory, Manufacture, Care and Application, by Morton Arendt. 285 pages, illustrations, 8vo. New York, D. Van Nostrand Company, Inc. 1928, price $4.50.

A Quantitative Study of Chromatic Adaptation. A dissertation presented to the Faculty of Bryn Mawr College by Mary Ruth Almack. 119 pages, illustrations, 8vo. 1928.

The Effect of Intensity of Light, State of Adaptation of the Eye, and Size of Photometric Field on the Visibility Curve. A study of the Purkinje Phenomenon. A dissertation presented to the Faculty of Bryn Mawr College by Louise L. Sloan, 89 pages, illustrations, plates, 8vo. 1928.

The Geology of Petroleum and Natural Gas, by Ernest Raymond Lilley, Sc.D. 524 pages, illustrations, 8vo. New York, D. Van Nostrand Company, Inc., 1928. price $6.00.

Chemical Encyclopædia, and Epitomized Digest of Chemistry and its Industrial Applications, by C. T. Kingzett, F.I.C. Fourth edition, 807 pages, 8vo. New York, D. Van Nostrand Company, Inc., 1928, price $10.00.

Michigan College of Mining and Technology. Bulletin 1927–1928, Announcement of Courses 1928–1929. 124 pages, illustrations, 8vo. Houghton, Mich., The College, 1928.

National Advisory Committee for Aeronautics. Technical Notes, No. 287, A dangerous seaplane landing condition, by Thomas Carroll. 3 pages, quarto No. 288, The reaction on a float bottom when making contact with water at high speeds, by H. C. Richardson. 4 pages, illustrations, quarto. Washington, Committee, 1928.

Report of the Commission appointed by Governor C. C. Young to investigate the causes leading to the failure of the St. Francis dam, near Saugus, California. 21 pages, 30 plates, 8vo. Sacramento, California State Printing Office, 1928.

CURRENT TOPICS

A Simple Method of Finding the Sound Absorbing Power of a Building Material. GUNNAR HEIMBURGER. (*Phys. Rev.*, Feb., 1928.) Prof. W. C. Sabine of Harvard developed a method of determining the absorption of building materials for sound. The material tested covered the walls of a room as in actual use and the human ear was the instrument for measuring the intensity of sound. Measurements thus obtained were slow in execution and involved considerable expense in the preparation of the room. In addition the ear requires long training before it becomes reliable for such work.

There is a second general method that requires a smaller amount of the material to be tested and uses, not the ear, but some really quantitative instrument, such as a telephone receiver, a hot wire microphone or a Rayleigh disc. The absorbing material closes the end of a tube that is adjusted to resonance with a steady source of sound, and measurements are made upon the system of standing waves set up within the tube, "usually by comparing the maximum energy value at an antinode with the minimum at a node." There is likely to be so great a disparity between the two quantities of energy to be measured that a small error in reading may cause a large final error. The author sets out to avoid this kind of error and develops a procedure that enables him to compare the absorbing powers of different substances, but not to measure them absolutely. The absorption coefficients are known for several materials so that comparison with one of these will lead indirectly to a knowledge of the coefficient. "The main idea of the method is to compare the values of the *maximum* sound intensity in the standing wave in the tube in the cases when the end of the tube is closed first with a hard material and then with the material under test. These values are always large enough to be accurately measurable, and with care in the experimental arrangements they may be made constant and reproducible."

In the paper a formula is derived for the ratio of the energy at an antinode of the tube when its end is closed by absorbent material to the value when its end does not absorb. The wave from the source of sound passes along the tube, is reflected from the closed end, traverses the tube in the opposite direction and is reflected a second time from the open end and continues up and down the tube with reflections at both ends. The formula contains the

absorption coefficient, a, at the closed end and also the coefficient, b, at the open end. The former, a, is the goal of the measurement. Fortunately b can be obtained since it is a constant for the same tube when carrying waves of one pitch. The ratio also can be measured so that the coefficient, a, can at last be calculated.

Two organ pipes, stated to be free from appreciable overtones, were used. The lower one with a frequency of 295 vibrations per sec. furnished the waves from which the data below were derived. The resonance tube 70 cm. long had a square cross-section 7.5 by 7.5 cm. For intensity measurements a Rayleigh disc consisting of a mica disc 1 cm. in diameter suspended by a quartz thread 2.5 cm. was inserted into the tube. This instrument showed that the energy at the four antinodes existing in the tube was not the same for all but decreased by 1½ per cent. in passing from the antinode nearest to the open end to the one farthest in the tube.

Seven materials, all with coefficients already known from experiments made upon them by Sabine's method, were studied. They were Celotex, Akoustikos, felt, Akoustolith tile and Rumford tile. By two different methods the coefficient of absorption at the open end was found to be .24. In five of the seven cases there was close agreement between the coefficient found by Sabine's method and that derived by the much simpler procedure described in this paper. The largest value of the absorption coefficient, 43 per cent., was, in the case of Akoustikos, ½ inch thick, and the smallest, .15 for Akoustolith tile. The ratios of the energies at antinodes varied from .109 to .417 for the two substances just named.

A method of direct practical value appears to have been developed by the author. G. F. S.

The Preparation of Large Single Crystals. H. S. RAMSPERGER and E. H. MELVIN. (*Jour. Optical Soc. Am.*, Dec., 1927.) Lyman found that a pure specimen of natural fluorite transmitted radiation of wave-length as short as 1230 A., but now suitable crystals of this substance are not available for the construction of vacuum spectrographs transmitting thus far into the ultra-violet. There is need of crystals larger in size and optically clearer. Even as little as .01 per cent. of certain impurities will notably reduce the transparency of the crystal in the region of very short wave-lengths. The purpose of the technique later described is to obtain large crystals of very pure compounds with a view to their use in optical researches in the ultra-violet.

There are two general methods of getting large crystals from molten masses. In one the liquid is cooled very slowly

by means of a device applied to its upper part. In the other the liquid cools from below upward. "Stober had shown that in the case of bismuth metal, sodium nitrate, and sodium chloride the entire dish could be crystallized as a single clear crystal. We have used this method, making some improvements in the apparatus." The crystal must start to form at some point and this point must be the lowest point of the containing dish. There must be a uniform temperature gradient from top to bottom so as to avoid the development of a second crystal and the flow of convection currents. Cooling must be so slow as to prevent the occurrence of strains. The authors found no great difficulty in meeting these conditions except in the avoidance of strain. All the molten material turned into one large crystal, but sometimes near the completion of cooling this broke up into smaller crystals that in polarized light showed evidence of strain. This was traced to the adhesion of the molten liquid to the platinum containing crucible. The metal has a thermal expansion coefficient different from the crystal. Due to this difference, as cooling proceeds, a state of strain is produced. A vain search was made for a material from which a dish could be made not wetted by the contained molten salts. Though platinum is wetted by all the salts used no better material was found. It was, however, used in foil .0025 cm. thick and free from alloy. The pure platinum was almost as malleable and soft as gold, and its thinness reduced the strains so that the resulting crystal no longer automatically broke.

The crucible in which the melting and subsequent crystallization took place was cylindrical with vertical sides closed below by a conical portion ending in a point where the crystal began its development. The crucible was surrounded by a block of insulating material. Both above and below it were electrical heating units. The compound in solid form was put into the crucible. The upper unit was turned on and the compound was raised almost to its melting point. Then the lower unit was brought into play and the substance was melted. By reduction of the lower current a gradual cooling was attained and the crystal began to form. Lowering of the upper current finally by slow stages brought the crystal to room temperature. "The crystallizing was usually done in 24 hours, and the cooling to room temperature in 100 to 120 hours." The variation of voltage on the electric line circuits made necessary the use of a thermostat. The

apparatus was applicable up to 1,500° C. Crystals of lithium fluoride, sodium chloride, sodium nitrate and mercuric bromide have been produced. The largest crystal obtained was of lithium fluoride. It filled the entire container, being $1\frac{3}{4}$ inches in diameter and $1\frac{1}{2}$ inches from top to bottom.

G. F. S.

The Motion of Water when Traversed by Rapidly Moving Spheres. CARL RAMSAUER. (*Ann. der Phys.*, Vol. 84, No. 22.) A steel sphere, used for ball bearings, was shot from a gun with smooth bore into a body of water. The experimental problem undertaken by the author was to photograph the water as the projectile passed through it. The ball was 11.003 mm. in diameter and had an initial velocity of 650 m./sec.

Much attention was given to securing a suitable container for the water. Glass was too fragile and too expensive. Celluloid proved itself satisfactory. A sheet of this material about 50 cm. wide and 60 cm. long was bent so as to form two vertical sides joined by a curved portion below. Two ends of celluloid as thin as paper were fastened to this bent sheet thus forming a trough open at the top. The end pieces had to be replaced after every shot, though the sides could be used several times. Sparks from Leyden jars provided the illumination for photographing the water. A timing device was operated by the water scattered by the impact of the ball. The ball went horizontally through the water, its path being about 7 cm. below the surface of the water so that it was surrounded on all all sides by some 7 to 8 cm. of the liquid. A series of photographs is reproduced showing the state of the water at different stages of the process. They are by necessity pictures of what occurred during different shots and not successive pictures during the same shot. A typical view, when the ball is a little more than half through the water, shows no disturbance in front of it. Behind it and extending from its momentary position back to the wall of the trough through which it entered there is a vacant space from which the water has been ejected. Near to the ball this space has the form of a paraboloid, farther back it is conical, while close to the end of the trough it becomes cylindrical. Its diameter in a rough sense increases from the projectile backward, the maximum diameter being dependent upon the distance in the water to which the ball has penetrated.

An inspection of the free surface of the water shows that there is far less distortion of it than would be expected. In some of the photographs the profile of the surface remains almost a straight line and careful examination is required to convince the observer that the water has moved upward at all. In cases for which the path of the ball lies nearer to the surface it is plainly seen that the water surface has been driven upwards. When the path lay 2.5 cm. below the surface the conical space formed behind the ball is clean but almost half of it lies above the level of the undisturbed water. Through the hole in the celluloid by which the ball enters the water a considerable quantity of the liquid is scattered backward. A smaller beam of the liquid emerges through the aperture made in the front wall of the trough. Even after the ball has left the containing vessel the empty space behind it continues its development within the vessel.

G. F. S.

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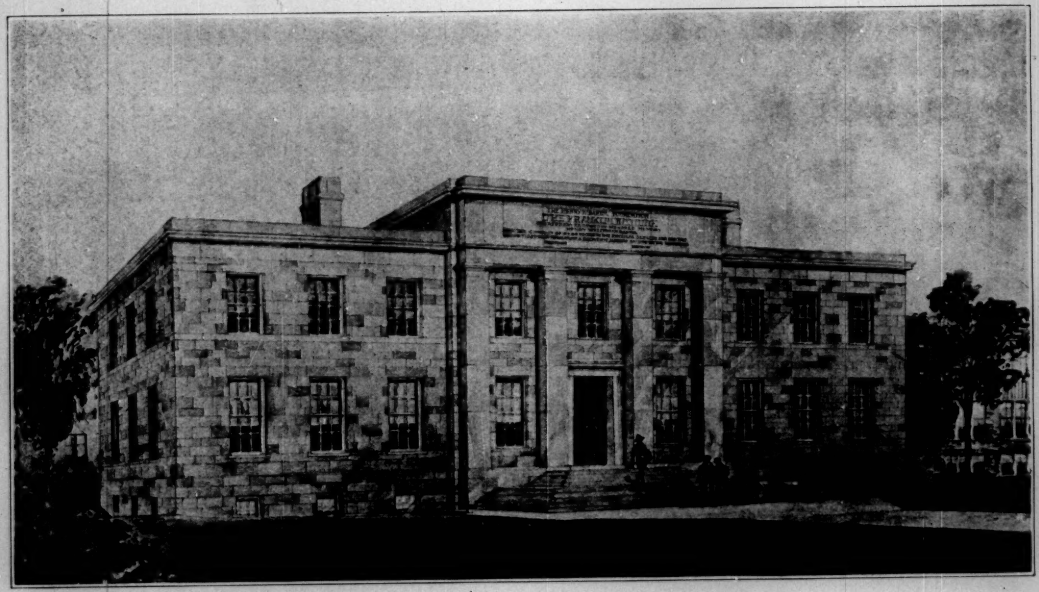

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